WEALE'S RUDIMENTARY SERIES

22

BUILDING

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RUDIMENTS OF THE

ART OF BUILDING.

In Five Sections—

GENERAL PRINCIPLES OF CONSTRUCTION; MATERIALS USED IN BUILDING; STRENGTH OF MATERIALS; USE OF MATERIALS; WORKING DRAWINGS, SPECIFICATIONS, AND ESTIMATES.

By EDWARD DOBSON, ASSOC.I.C.E. AND M.I.B.A.
AUTHOR OF "THE RAILWAYS OF BELGIUM," ETC.

With numerous Illustrations.

EIGHTH EDITION.

LONDON:
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LUDGATE HILL.
1871.

ADVERTISEMENT.

FIVE very large impressions of this little treatise have been exhausted in less than ten years, a sufficient proof of its great utility and the estimation in which it is held. Indeed, it is within the mark to state that, if not the very best, it is looked upon as one of the best treatises to be placed in the hands of the young student whose future walk in life is destined to be that of a builder, architect, or engineer.

This sixth edition contains an APPENDIX OF NOTES, by Robert Mallet, A.M., F.R.S., bringing forward new facts, or principles, which, at the date of the original publication, had been less clearly developed than at present, and referring the reader to various sources of more enlarged special information in works not noticed by the Author himself.

New editions of Mr. Dobson's other treatises, intended to supplement his "Rudiments of the Art of Building," have also just been issued—the "Principles of Brickmaking, and Manufacture of Bricks and Tiles," supervised by Professor Charles Tomlinson; "Masonry and Stone-cutting, with Principles of Masonic Projection;" and the "Treatise on Foundations and Concrete Work," with notes by G. Dodd, Esq. These little manuals were published by the Author as companions to one another.

May, 1867.

PREFACE.

In offering this little volume to the public, it may be desirable to say a few words, by way of preface, as to the object and character of the work. It has been written at the suggestion of the publisher, to accompany the Rudimentary Series, and as a first book on the Art of Building, intended for the use of young persons who are about to commence their professional training for any pursuit connected with the erection of buildings; and, also, for the use of amateurs who wish to obtain a general knowledge of the subject without devoting to it the time requisite for the study of the larger works that have been written on the different branches of construction.

To avoid unnecessarily extending the limits of the work, those subjects are omitted which are treated of in other volumes of this series, as Building Stone, Brick-making, and the Composition of Colours and Varnishes. For the same reason little has been said of the manufacture of glass and the smelting of metallic ores, because they have been repeatedly treated of in various elementary works, whilst a considerable space has been devoted to the consideration of the differences between hot and cold blast irons, and to the description of the operations of the iron-founder, subjects which are not generally to be met with but in expensive works.

The equilibrium of retaining walls is a subject which has long engaged the attention of mathematicians with little practical success, the results arrived at by different eminent writers being quite at variance with each other. For the chapter on this subject a few simple formulæ are given, which embrace all the conditions of the thrust of the earth and of the resistance of the

wall, the friction of the earth against the back of the wall being also taken into account *.

In the article on the strength of cast-iron flanged beams a simple rule is given for calculation, founded on the assumption that the position of the neutral axis in a cast-iron rectangular beam, at the time of fracture, is at about $\frac{1}{7}$th of its whole depth below its top surface, which is now pretty generally admitted to be the case. Amongst various works, the following have been carefully consulted during the composition of this little work. The publications of the Institution of Civil Engineers and of the Royal Institute of British Architects, Professional Papers of the Royal Engineers, Weale's Quarterly Papers on Engineering and Architecture, Weale's Bridges, the Works of Peter Nicholson, Gwilt's Encyclopædia of Architecture, Dr. Ure's Dictionary of Arts and Manufactures, Tredgold's Carpentry, the works of Pasley and Vicat on Limes and Cements, Aikin's Papers on Arts and Manufactures, Barlow on the Strength of Materials, Tredgold and Hodgkinson on Cast Iron, and Bartholomew on Practical Specifications; all these works will be found extremely valuable to the student.

I have great pleasure in acknowledging the kind assistance of my friend Mr. H. W. Kirby, C.E., in the articles on the equilibrium of retaining walls, and on the strength of cast-iron beams; to whom I am also indebted for the valuable notes appended to the article on retaining walls.

The articles on Iron-Founding, Carpenter and Joiner's Work, and House-Painting, have been carefully revised by friends practically engaged in those pursuits.

E. Dobson.

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RUDIMENTS

OF THE

ART OF BUILDING.

SECTION I.

GENERAL PRINCIPLES OF CONSTRUCTION

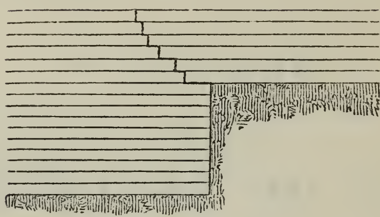
FOUNDATIONS.

1. In preparing the foundation for any building, there are two sources of failure which must be carefully guarded against: viz., inequality of settlement, and lateral escape of the supporting material; and, if these radical defects can be guarded against, there is scarcely any situation in which a good foundation may not be obtained.

2. *Natural Foundations.*—The best foundation is a *natural* one, such as a stratum of rock, or compact gravel. If circumstances prevent the work being commenced from the same level throughout, the ground must be carefully *benched out*, i.e. cut into horizontal steps, so that the courses may all be perfectly level. It must also be borne in mind that all work will settle, more or less, according to the perfection of the joints, and therefore in these cases it is best to bring up the foundations to a uniform level, with large blocks of stone, or with concrete, before commencing the superstructure, which would otherwise settle most over the deepest parts, on account of the greater number of mortar

joints, and thus cause unsightly fractures, as shown in fig. 1.

Fig. 1.



3. Many soils form excellent foundations when kept from the weather, which are worthless when this cannot be effected. Thus blue shale, which is often so hard when the ground is first opened as to require blasting with gun powder, will, after a few days' exposure, slake and run into sludge. In dealing with soils of this kind nothing is required but to keep them from the action of the atmosphere. This is best done by covering them with a layer of concrete, which is an artificial rock, made of sand and gravel, cemented with a small quantity of lime. For want of this precaution many buildings have been fractured from top to bottom by the expansion and contraction of their clay foundations during the alternations of drought and moisture, to which they have been exposed in successive seasons.

4. *Artificial Foundations* — Where the ground in its natural state is too soft to bear the weight of the proposed structure, recourse must be had to artificial means of support, and, in doing this, whatever mode of construction be adopted, the principle must always be that of extending the bearing surface as much as possible; just in the same way, that, by placing a plank over a dangerous piece of ice, a couple of men can pass over a spot which would not bear the weight of a child. There are many ways of doing this —as by a thick layer of concrete, or by layers of planking, or by a network of timber, or these different methods may

be combined. The weight may also be distributed over the entire area of the foundation by inverted arches.

5. The use of timber is objectionable where it cannot be kept constantly wet, as alternations of dryness and moisture soon cause it to rot, and for this reason concrete is very extensively used in situations where timber would be liable to decay.

6. In the case of a foundation partly natural and partly artificial, the utmost care and circumspection are required to avoid unsightly fractures in the superstructure; and it cannot be too strongly impressed on the mind of the reader, that it is not an *unyielding*, but a *uniformly yielding* foundation that is required, and that it is not the *amount*, so much as the *inequality*, of settlement that does the mischief.

The second great principle which we laid down at the commencement of this section was—To prevent the lateral escape of the supporting material. This is especially necessary when building in running sand, or soft buttery clay, which would ooze out from below the work, and allow the superstructure to sink. In soils of this kind, in addition to protecting the surface with planking, concrete, or timber, the whole area of the foundation must be inclosed with piles driven close together;—this is called *sheet-piling*.

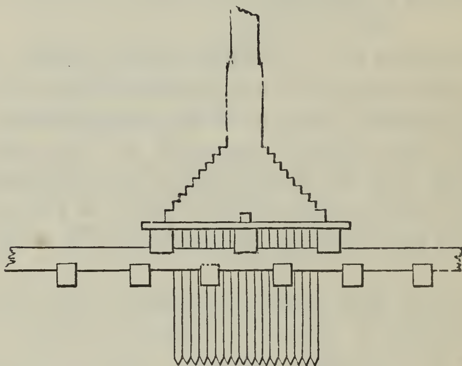
An example of a wide-spread foundation in soft ground is shown in fig. 2 (p. 4), which is a section of the foundation for the walls of the Leyden station of the Amsterdam and Rotterdam Railway, built A.D. 1843.* The station stands upon such bad ground, that it was necessary to support the walls upon a kind of raft resting on oak piles.

7. Where there is a hard stratum below the soft ground, but at too great a depth to allow of the solid work being brought up from it without greater expense than the circumstances of the case will allow, it is usual to drive down

* From the "Minutes of Proceedings of the Institution of Civil Engineers," 1844.

wooden piles, shod with iron, until their bottoms are firmly fixed in the hard ground. The upper ends of the piles are then cut off level, and covered with a platform of timber on which the work is built in the usual way

Fig. 3.



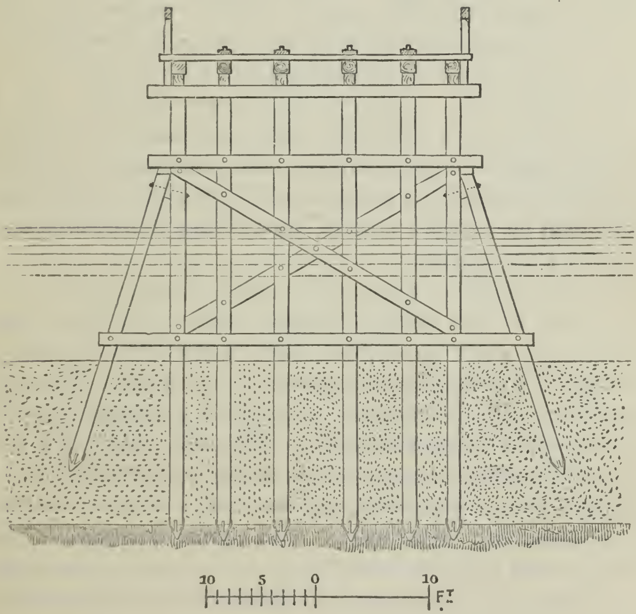
8. Where a firm foundation is required to be formed in a situation where no firm bottom can be found within an available depth, piles are driven, to consolidate the mass, a few feet apart over the whole area of the foundation, which is surrounded by a row of sheet-piling to prevent the escape of the soil; the space between the pile heads is then filled to the depth of several feet with stones or concrete, and the whole is covered with a timber platform, on which to commence the solid work.

9. *Foundations in Water.*—Hitherto we have been describing ordinary foundations; we now come to those cases in which water interferes with the operations of the builder, oftentimes causing no little trouble, anxiety, and expense.

Foundations in water may be divided under three heads: 1st, Foundations formed wholly with piles. 2nd, Solid foundations laid *on* the surface of the ground, either in its natural state, or roughly levelled by dredging. 3rdly, Solid foundations laid *below* the surface, the ground being laid dry by cofferdams

10. *Foundations formed wholly of piles.*—The simplest foundations of this kind are those formed by rows of wooden piles braced together so as to form a skeleton pier for the support of horizontal beams; and this plan is often adopted in building jetties, piers of wooden bridges, and similar erections where the expense precludes the adoption of a more permanent mode of construction; an example of this kind is shown in fig. 3.

Fig. 8.



In deep water the bracing of the piles becomes a difficult matter, and an ingenious expedient for effecting this was made use of by Mr. Walker, in the erection of the Ouse Bridge, on the Leeds and Selby Railway, A.D. 1840. This consisted in rounding the piles to which the braces are attached for a portion of their length, to allow the cast-iron

sockets in which they rest to descend and take a solid bearing upon the square shoulders of the brace-piles. After the brace-piles were driven, the braces were bolted into their sockets and dropped down to their required position, and their upper ends were then brought to their places and bolted to the superstructure.

11. There is always, however, a great objection to the use of piles partly above and partly under water, namely, that, from the alternations of dryness and moisture, they soon decay at the water-line, and erections of timber require extensive repairs from this cause. In tidal waters, too, they are often rapidly destroyed by the worm, unless great expense is undergone in sheathing them with copper.

To obviate the inconveniences attending the use of timber, cast iron is sometimes used as a material for piles: but this again is objectionable in salt water, as the action of the sea-water upon the iron converts it into a soft substance which can be cut with a knife, resembling the Cumberland lead used for pencils.

12. In situations where a firm hold cannot be obtained for a pile of the ordinary shape, such as shifting sand, Mitchell's patent screw-piles may be used with great advantage. These piles terminate at the bottom in a large iron screw 4 ft. in diameter, which, being screwed into the ground, gives a firm foot-hold to the pile. This is a very simple and efficient mode of obtaining a foundation where all other means would fail, and has been used in erecting light-houses on sand-banks with great success. The Maplin sand light-house at the mouth of the Thames, and the Fleetwood Lighthouse, at Fleetwood, in Lancashire, both erected A.D. 1840, may be instanced.

13. An ingenious system of cast-iron piling was adopted by Mr. Tierney Clark, in the erection of the Town Pier at Gravesend, Kent, A.D. 1834, in forming a foundation for the cast-iron columns supporting the superstructure of the T head of the pier. Under the site of each column were driven three cast-iron piles, on which an adjusting plate was

firmly keyed, forming a broad base for the support of the column, which was adjusted to its correct position, and bolted down to the adjusting plate

14. A kind of foundation on the same principle as piling has been lately much used in situations where ordinary piling cannot be resorted to with advantage. The method referred to consists in sinking hollow cast-iron cylinders until a hard bottom is reached. The interior of the cylinder is then pumped dry, and filled up with concrete or some equally solid material, thus making it a solid pier on which to erect the superstructure. The cylinders are made in lengths, which are successively bolted together as each previous length is lowered, the excavation going on at the bottom, which is kept dry by pumping. It often happens, however, in sinking through sand, that the pressure of the water is so great as to blow up the sand at the bottom of the cylinder; and, when this is the case, the operation is carried on by means of a large auger, called a miser, which excavates and brings up the materials without the necessity of pumping out the water. The lower edge of the bottom length of each cylinder is made with a sharp edge, to enable it to penetrate the soil with greater ease, and to enter the hard bottom stratum on which the work is to rest. This method was adopted by Mr. Redman in the erection of the Terrace Pier at Gravesend, Kent, finished A.D. 1845.

15. Before closing our remarks on pile foundations, we must mention a very curious system of carrying up a foundation through loose wet sand, which is practised in India and China, and is strictly analogous to the sinking of cast-iron cylinders just described.

It consists in sinking a series of wells close together, which are afterwards arched over separately, and covered with a system of vaulting on which the superstructure is raised. The method of sinking these wells is to dig down, as far as practicable, without a lining of masonry, or until water is reached; a wooden curb is then placed at the bottom of the excavation, and a brick cylinder raised upon it

to the height of 3 or 4 ft. above the ground. As soon as the work is sufficiently set, the curb and the superincumbent brick-work are lowered by excavating the ground under the sides of the curb, the peculiarity of the process being that the well-sinker works under water, frequently remaining submerged more than a minute at a time. These cylinders have been occasionally sunk to a depth of 40 ft.

16. *Solid Foundations simply laid on the Surface of the Ground.*—Where the site of the intended structure is perfectly firm, and there is no danger of the work being undermined by any scour, it will be sufficient to place the materials on the natural bottom, the inequalities of surface being first removed by dredging or blasting.

17. *Pierre perdue.*—The simplest mode of proceeding is to throw down masses of stone at random over the site of the work until the mass reaches the surface of the water, above which the work can be carried on in the usual manner. This is called a foundation of "*pierre perdue*," or random work, and is used for breakwaters, foundations of sea-walls, and similar works. Plymouth breakwater is an example on a large scale.

18. *Coursed Masonry.*—Another way, much used in harbour work, is to build up the work from the bottom (which must be first roughly levelled) with large stones, carefully lowered into their places; and this is a very successful method where the stones are of sufficient size and weight to enable the work to withstand the run of the sea. The diving-bell affords a ready means of verifying the position of each stone as it is lowered.

19. *Béton.*—On the Continent foundations under water are frequently executed with blocks of béton or hydraulic concrete, which has the property of setting under water. The site of the work is first inclosed with a row of sheet piling, which protects the béton from disturbance, until it has set. This system is of very ancient date, being described by Vitruvius, and was practised by the Romans, who

have left us many examples of it on the coast of Italy. The French engineers have used béton in the works at Algiers, in large blocks of 324 cubic feet, which were floated out and allowed to drop into their places from slings. This method, which proved perfectly successful, was adopted in consequence of the smaller blocks first used being displaced and destroyed by the force of the sea.

20. *Caissons.*—A caisson is a chest of timber, which is floated over the site of the work, and, being kept in its place by guide piles, is loaded with stone until it rests firmly on the ground. The masonry is then built on the bottom of the caisson, and when the work reaches the level of the water the sides of the caisson are removed.

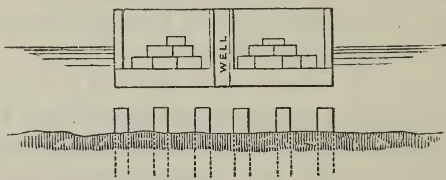
This method of building has been much used on the Continent, but is not much practised in this country. Westminster Bridge, London, is a noted instance of its failure. The bottom of the river has been scoured out to a depth of several feet since the erection of the bridge; and the foundations of the piers remained in a dangerous state until they were secured in the recent repairs by driving sheet-piling all round them, and underpinning the portions which had been undermined.

21. An improvement on the above method consists in dredging out the ground to a considerable depth, and putting in a thick layer of béton on which to rest the bottom of the caisson.

22. There is a third method of applying caissons which is practised by our continental neighbours, and which is free from the objections which commonly attend the use of caissons. A firm foundation is first formed by driving piles a few feet apart over the whole site of the foundation. The tops of the piles are then sawn off under water, just enough above the ground to allow of their being all cut to the same level. The caisson is then floated over the piles, and, when in its proper position, is sunk upon them, being kept in its place by a few piles left standing above the others, the water being kept out of the caisson by a kind of well con-

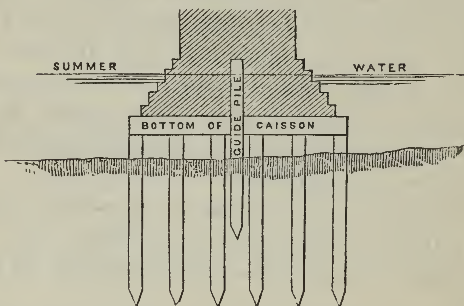
structed round each of these internal guide piles, which are built up into the masonry This method of building in caissons on pile foundations is shown in figs. 4 and 5. The

Fig. 4.



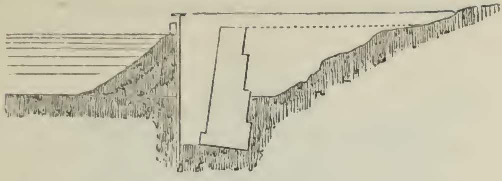
piers of the Pont du Val Benoît at Liége, built A.D. 1842, which carries the railway across the Meuse, have been built on pile foundations in the manner here described.

Fig. 5.



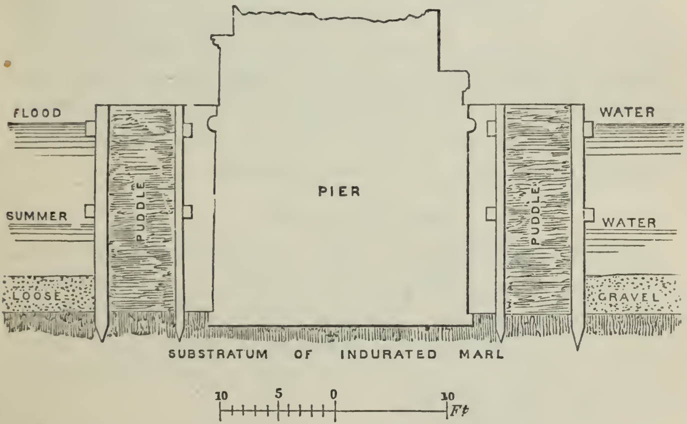
23 *Solid Foundations laid in Cofferdams.*—There are many circumstances under which it becomes necessary to lay the bottom dry before commencing operations. This is done by inclosing the site of the foundation with a water-tight wall of timber, from within which the water can be pumped out by steam power or otherwise. Sometimes, in shallow water, it is sufficient to drive a single row of piles only, the outside being protected with clay, as shown in fig. 6; but in deep water two or even four rows of piles will be required, the space between them being filled in with well-rammed *puddle*, so as to form a solid water-tight mass

Fig. 8



(See fig. 7.) The great difficulties in the construction of a cofferdam are—1st, to keep it water-tight; and, 2nd, to support the sides against the pressure of the water outside, which in tidal waters is sometimes so great as to render it necessary to allow a dam to fill to prevent its being crushed

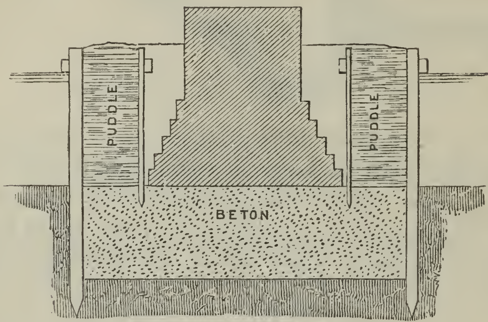
Fig. 7.



24. In order to save timber, and to avoid the difficulty of keeping out the bottom springs, it has been proposed by a French engineer, after driving the outer row, to dredge out the area thus inclosed, and fill it up to a certain height with béton. The cofferdam is then to be completed by driving an inner row of piles resting on the béton, and puddling between the two rows in the usual manner; and the

masonry is carried up on the béton foundation thus prepared. This construction is shown in fig. 8.

Fig. 8.



25. The limits of the present volume prevent our entering into any detail as to the preparation of concrete and béton, the methods in use for driving piles, and the construction of cofferdams: the reader who wishes to pursue the subject further is referred to the volume of this series on "Foundations and Concrete Works," where he will find a detailed description of these operations.

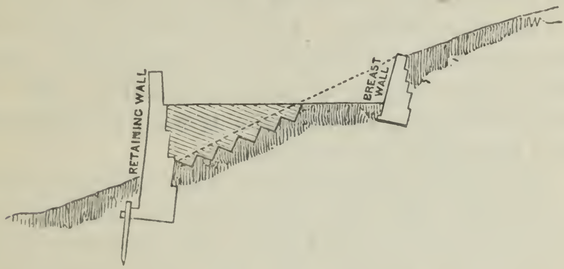
RETAINING WALLS.

26. The name of *retaining wall* is applied generally to all walls built to support a mass of earth in an upright or nearly upright position; but the term is, strictly speaking, restricted to walls built to retain an artificial bank, those erected to sustain the face of the solid ground being called *breast walls*. (See fig. 9.)

27. *Retaining Walls.*—Many rules have been given by different writers for calculating the thrust which a bank of earth exerts against a retaining wall, and for determining the form of wall which affords the greatest resistance with the least amount of material. The application of these rules to practice is, however, extremely difficult, because we have no means of ascertaining the exact manner in which earth acts against a wall; and they are, therefore, of little

value except in determining the general principles on which the stability of these constructions depends. (See Note A, p. 155.)

Fig. 9.



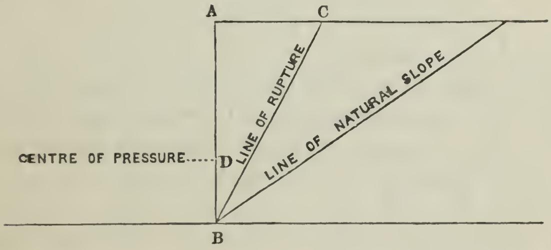
28. The calculation of the stability of a retaining wall divides itself into two parts.

1st. The thrust of the earth to be supported.

2nd. The resistance of the wall.

29. Definitions (see fig. 10).—*The line of rupture* is that along which separation takes place in case of a *slip* of earth.

Fig. 10.



The slope which the earth would assume, if left totally unsupported, is called the *natural slope*, and it has been found that the line of rupture generally divides the angle formed by the natural slope and the back of the wall into nearly equal parts.

The *centre of pressure* is that point in the back of the wall above and below which there is an equal amount of pressure; and this has been found by experiment and calcula-

tion to be at $\frac{2}{3}$rds of the vertical height of the wall from its top.

The wall is assumed to be a solid mass, incapable of sliding forward, and giving way only by turning over on its front edge as a fulcrum. In the annexed diagrams the foundations of the walls have, in all cases, been omitted, to simplify the subject as much as possible. The term *slope* in the following investigation is used as synonymous with the expression *line of rupture.*

30. *Amount and Direction of the Thrust.*—There are two ways in which this may be calculated:—1st, By considering the earth as a solid mass sliding down an inclined plane, all slipping between the earth and the back of the wall being prevented by friction. This gives the *minimum* thrust of the earth 2nd, By assuming the particles of earth to have so little cohesion, that there is no friction either on the slope or against the back of the wall. This method of calculation gives the *maximum* thrust.

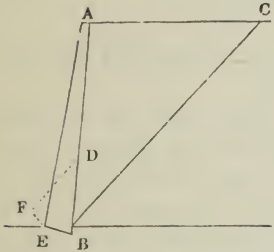
The real thrust of any bank will probably be somewhere between the two, depending on a variety of conditions which it is impossible to reduce to calculation; for, although we may by actual experiments with sand, gravel, and earths of different kinds, obtain data whence to calculate the thrust exerted by them in a perfectly dry state, another point must be attended to when we attempt to reduce these results to practice, viz. the action of water, which, by destroying the cohesion of the particles of earth, brings the mass of material behind the wall into a semi-fluid state, rendering its action more or less similar to that of a fluid according to the degree of saturation.

The tendency to slip will also very greatly depend on the manner in which the material is *filled* against the wall. If the ground be *benched out* (see fig. 9), and the earth well punned in layers inclined *from* the wall, the pressure will be very trifling, provided only that attention be paid to surface and back drainage. If, on the other hand, the bank be tipped in the usual manner in layers sloping *towards* the

wall, the full pressure of the earth will be exerted against it. and it must be made of corresponding strength.

31. *Calculation of Minimum Thrust.*—The weight of the prism of earth represented by the triangle A B C, fig. 10, will be directly as the breadth A C, the height being constant; and the inclination of B C remaining constant, but the height varying, the weight will be as the square of the height. If, therefore, we call the weight of the prism A B C, W, the breadth A C, b, the height A B, h, and the specific gravity of the earth, s, we

Fig. 11.



shall have $W = \frac{b\,h\,s}{2}$ If we call the thrust of W in the direction of the slope, W′, then (neglecting friction), on the principle of the inclined plane, W will be to W′ as the length of the incline is to its height; or, calling the length B C, l, then

$$l : h :: W : W' = \frac{h\,W}{l} = \frac{b\,h^2\,s}{2\,l}.^*$$

The effect of the weight of the prism A B C to overturn the wall will be as W′ multiplied by the leverage E F, fig. 11, found by letting fall the perpendicular E F, from the front edge of the wall, upon D F, drawn through the centre of pressure in a direction parallel to the slope. When D F

* The value of W′ here given will increase with the length of A C in a constantly decreasing ratio, never exceeding $\frac{h^2\,s}{2}$ supposing the back of the wall to be upright. But in practice the friction must always be taken into consideration; and, as this increases directly as A C, there will be a limit at which the thrust and the resistance balance each other, this limit being the natural slope; and, as the thrust and the resistance increase with the length of A C in different ratios, there will be a point at which the effective thrust is greatest, or, in other words, a slope of maximum thrust which determines the position of the line of rupture.

passes through E, then $EF=0$, and the thrust has no tendency to overturn the wall; and, when D F falls within the base of the wall, E F becomes a negative quantity, the thrust increasing its stability. Calling the overturning thrust T, we have

$$T = W' \times EF = \frac{b h^2 s \times EF}{2l},$$

the value of E F * depending on the inclination of the slope and the width of the base of the wall

32. *Calculation of Maximum Thrust.*—If we consider the moving mass to slide freely down the slope, and the friction between the earth and the back of the wall to be so slight as to be inappreciable, then the prism A B C will act as a wedge, with a pressure perpendicular to the back of the wall, which will be the same whatever the inclination of B C, the height and inclination of the back of the wall being constant, and as the square of the height where the height varies, the pressure being the least when the back of the wall is vertical; for calling the pressure P, and drawing A I, fig. 12, perpendicular to B C, we have, on the principle of the wedge,

$$AI : AB :: W' : P = \frac{W' \times AB}{AI} = \frac{b h^2 s \times AB}{2l \times AI}$$

and by construction $bh = l\,AI$, as they are each equal to twice the area of the triangle A B C; therefore, by substitution,

$$P = \frac{l\,AI\,h s \times AB}{2l\,AI} = \frac{h s \times AB}{2}.$$

The effect of the prism A B C to overturn the wall will be P multiplied by the leverage E F,† which will be found by

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* $EF = \frac{h}{l} \times \left(\frac{b}{3} - EB\right)$ and

$$T = W' \times EF = \frac{b h^2 s}{2l} \times \frac{h}{l}\left(\frac{b}{3} - EB\right) - \frac{b h^3 s}{2l^2} \times \left(\frac{b}{3} - EB\right).$$

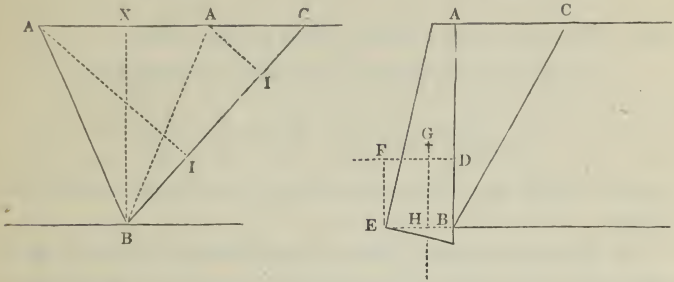
† Calling the angle $XAB = \theta$

$$EF = \frac{AB}{3} \pm \frac{EB \cdot AX}{AB} = \frac{h}{3}\,\text{cosec.}\,\theta \pm EB\cos.\theta.$$

And

drawing D F, fig. 13, at right angles to the back of the wall through the centre of pressure, and making E F

Fig. 12. *Fig.* 13.



perpendicular to it; then calling the overturning thrust, as before, T,

$$T = P \times E F = \frac{A B \times h s \times E F}{2}.$$

When D F passes through E, then $E F = 0$, and the thrust has no tendency to overturn the wall; and, if D F falls within the base, the thrust will *increase* its stability. When the back of the wall is vertical, then

$$A B = h \text{ and } E F = \frac{h}{3} \text{ and } T = \frac{h^3 s}{6}.$$

33. These results show that, where the friction of the earth against the slope and the back of the wall is destroyed by the filtration of water, the action of the earth will be precisely similar to that of a column of water of the height of the wall. The pressure upon the side of any vessel is the half of the pressure that would take place upon the bottom if of the same area. Now, calling the specific gravity of the water s, the pressure upon the bottom, sup-

---

$$\text{And } T = P \times E F = \frac{A B \,.\, h s}{2} \times \left(\frac{A B}{3} \pm \frac{E B \,.\, A X}{A B} \right) = \frac{h s}{2} \times \left(\frac{A B^2}{3} \pm E B \,.\, A X \right)$$

The positive sign is to be used when the back of the wall leans backwards; the negative, when it leans forwards.

posing its length to be A B, would be $h\,s\,\text{A B}$; therefore the pressure upon the side will be

$$\frac{h\,s\,\text{A B}}{2}\text{; and } \text{T} = \text{P} \times \text{E F} = \frac{h s\,\text{AB.E F}}{2}.$$

And, where the back of the wall is vertical, then

$$\text{A B} = h \text{ and E F} = \frac{h}{3} \text{ as above. Therefore}$$

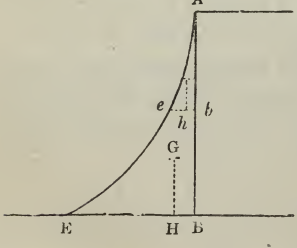
$$\text{P} = \frac{h^2 s}{2} \text{ and } \text{T} = \frac{h^2 s}{2} \times \frac{h}{3} = \frac{h^3 s}{6};$$

which results are precisely the same as those arrived at above.

34. *Resistance of the Wall.*—Considering the wall as a solid mass, the effect of its weight to resist an overturning thrust will be directly as the horizontal distance E H from its front edge to a vertical line drawn through G, the centre of gravity of the wall, fig. 13; or calling the resistance R, and the weight of the wall w, then $\text{R} = w \times \text{E H}$. E H will be directly as E B, the proportions of the wall being constant; therefore a wall of triangular section will afford more resistance than a rectangular one of equal sectional area, the base of a triangle being twice that of a rectangle of equal height and area.

If the wall be built with a curved concave batter, fig. 14, E H will be still greater than in the case of a triangular wall of equal sectional area; and, if the wall were one solid mass incapable of fracture, this form would offer more resistance than the triangular. But, as this is not the case, we may consider any portion of the wall cut off from the bottom by a level line to be a distinct wall resting upon the lower part as a foundation.

Fig. 14.



Imagine A e b to be a complete wall capable of turning upon e as a fulcrum. The resistance would be considerably less than that of the corresponding portion of a triangular

wall. In the case of a triangular wall the proportions of the resistance to the thrust will be the same throughout its height. In the case of a rectangular one, the resistance will bear a greater proportion to the thrust, the greater the distance from the bottom. In the case of a wall with a concave curved batter, the reverse of this takes place.

The value of E H will be greatest when E H=E B, the wall will be then exactly balanced on H; but in practice this limit should never be reached, for fear the wall should become crippled by depending on the earth for support. The value of E H will be least when H coincides with E, which opposite limit also is never reached in practice—for obvious reasons—as the wall would in this case overhang its base, and be on the point of falling forward.

35. The increased leverage is not the only advantage gained by the triangular form of wall. In the foregoing investigation, we have considered the wall as a solid mass turning on its front edge. Now, practically, the difficulty is not so much to keep the wall from overturning as to prevent the courses from sliding on each other.

In an upright wall built in horizontal courses, the chief resistance to sliding arises from the adhesion of the mortar; but, if the wall be built with a sloping or *battering* face, the beds of the courses being inclined to the horizon, the resistance to the thrust of the bank is increased in proportion to the tendency of the courses to slide down towards the bank; thus rendering the adhesion of the mortar merely an additional security. The importance of making the resistance independent of the adhesion of the mortar is obviously very great, as it would otherwise be necessary to delay backing up a wall until the mortar were thoroughly set, which might require several months.

36. The exact determination of the thrust which will be exerted against a wall of given height is not possible in practice; because the thrust depends on the cohesion of the earth, the dryness of the material, the mode of backing up the wall, and other conditions which we have no means

of ascertaining. Experience has, however, shown that the base of the wall should not be less than one-fourth, and the batter or slope not less than one-sixth of the vertical height, wherever the case is at all doubtful

37. The results of the above investigation are illustrated in figures 15, 16, 17, 18, and 19, which show the relative sectional areas of walls of different shapes, that would be required to resist the pressure of a bank of earth 12 feet high.

Fig. 15.

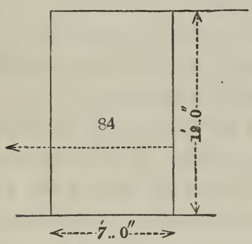


Fig. 16.

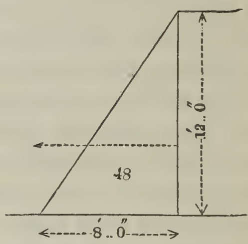


Fig. 17.

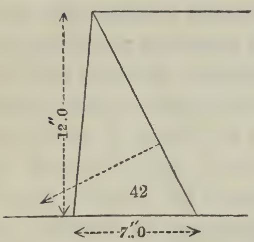
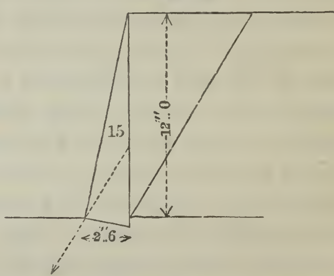


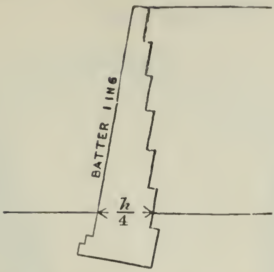
Fig. 18.



The first three examples are calculated to resist the maximum, and the fourth, the minimum, thrust; whilst the last figure (fig. 19) shows the modified form usually adopted in practice.

38. It is sometimes necessary in soft ground to protect the *toe* or front edge of a retaining wall with sheet-piling, to prevent it from being forced forward; this is shown in fig. 9.

Fig. 19.



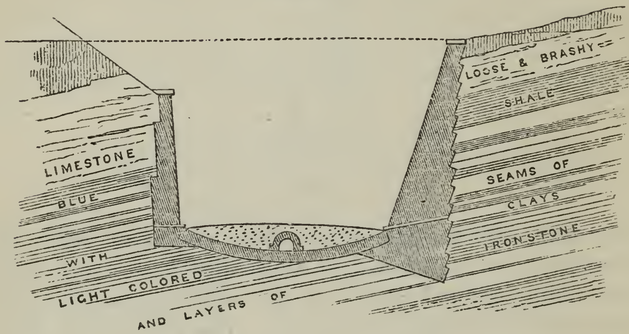
39. *Counterforts.*—Retaining walls are often built with counterforts, or buttresses, at short distances apart, which allow of the general section of the wall being made lighter than would otherwise be the case. The principle on which these counterforts are generally built is, however, very defective, as they are usually placed *behind* the wall, which frequently becomes torn from them by the pressure of the earth. The strength of any retaining wall would, however, be greatly increased were it built as a series of arches, abutting on long and thin buttresses; but the loss of space that would attend this mode of construction has effectually prevented its adoption except in a few instances.

40. *Breast Walls.*—Where the ground to be supported is firm, and the strata are horizontal, the office of a breast wall is more to protect, than to sustain the earth. It should be borne in mind that a trifling force, skilfully applied to unbroken ground, will keep in its place a mass of material which, if once allowed to move, would crush a heavy wall; and, therefore, great care should be taken not to expose the newly opened ground to the influence of air and wet for a moment longer than is requisite for sound work, and to avoid leaving the smallest space for motion between the back of the wall and the ground.

41. The strength of a breast wall must be proportionately increased when the strata to be supported incline

towards the wall, as in fig. 20: where they incline from it, the wall need be little more than a thin facing to protect the ground from disintegration.

Fig. 20.



42. The preservation of the natural drainage is one of the most important points to be attended to in the erection of breast walls, as upon this their stability in a great measure depends. No rule can be given for the best manner of doing this; it must be a matter for attentive consideration in each particular case

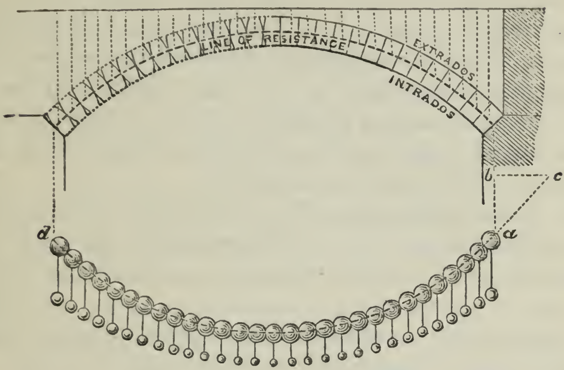
ARCHES.

43. An arch in perfect equilibrium may be considered as a slightly elastic curved beam, every part of which is in a state of compression, the pressure arising from the weight of the arch and its superincumbent load being transmitted to the abutments on which it rests in a curved line called the *curve of equilibrium*, passing through the thickness of the arch.

44. The wedge-shaped stones of which a stone arch is composed are called the *voussoirs*. The upper surface of an arch is called its *extrados*, and the lower surface its *intrados* or *soffit* (see fig. 21). Theoretically, a stone arch might give way by the sliding of the voussoirs on each other; but in practice the friction of the material and the adhesion of the mortar is sufficient to prevent this, and failure takes place

in the case of an overloaded arch by the voussoirs turning on their edges.

Fig. 21.



45. The curve of equilibrium will vary with the rise and span of the arch, the depth of the arch stones, and the distribution of the load, but it will always have this property, namely, that the horizontal thrust will be the same at every part of it. In order that an arch may be in perfect equilibrium, its curvature should coincide with that of the curve of equal horizontal thrust; if, from being improperly designed or unequally loaded, this latter curve approaches either the intrados or the extrados, the voussoirs will be liable to fracture from the pressure being thrown on a very small bearing surface; and if it be not contained within the thickness of the arch, failure will take place by the joints opening, and the voussoirs turning on their edges.

46. The manner in which the curve of equilibrium is affected by any alteration in the load placed upon an arch may readily be seen by making an experimental equilibrated arch with convex voussoirs, as shown in fig. 21. When bearing its own weight only, the points of contact of the voussoirs will lie wholly in the centre of the thickness of the arch; when loaded at the crown, the points of contact will approach the extrados at the crown, and the intrados

at the haunches; and, if loaded at the haunches, the reverse effect will take place.

47. If a chain be suspended at two points, and allowed to hang freely between them, the curve it takes is the curve of equilibrium of an arch of the same span and length on soffit, in which the weights of the voussoirs correspond to the weights of the links of the chain, and would be precisely the same as that marked out by the points of contact of the curved voussoirs of an experimental arch of the same dimensions built as above described.

48. In designing an arch, two methods of proceeding present themselves: we may either confine the load to the weight of the arch itself or nearly so, and suit the shape of the arch to a given curve of equilibrium, or we may design the arch as taste or circumstances may dictate, and load it until the line of resistance coincides with the curve thus determined upon.

The Gothic vaults of the middle ages were, in a great measure, constructed on the first of these methods, being in many cases only a few inches in thickness, and the curvature of the main ribs coinciding very nearly with their curves of equal horizontal thrust. We have no means of ascertaining whether this was the result of calculation or experiment; probably the latter, but the principle was evidently understood.

At the present day, the requirements of modern bridge building often leave the architect little room for choice in the proportions of his arches, or the height and inclinations of the roadway they are to carry; and it becomes necessary to calculate with care the proportion of the load which each part of the arch must sustain, in order that the curve of equilibrium may coincide with the curvature of the arch

49. The formulæ for calculating the equilibration of an arch are of too intricate a nature to be introduced in these pages; but the principles on which they depend are very simple

Let it be required to construct a stone arch of a given curvature to support a level roadway, as shown in fig. 21,

and to find the weight with which each course of voussoirs must be loaded to bring the arch into equilibrium.

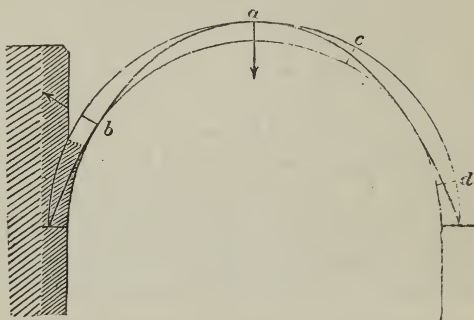
Draw the centre line of the arch to a tolerably large scale in an inverted position on a vertical plane, as a drawing board, for instance, and from its springing points *a*, *d*, suspend a fine silk thread of the length of the centre line strung with balls of diameter and weight corresponding to the thickness and weight of the voussoirs of the arch ; then from the centre of each ball suspend such a weight as will bring the thread to the curve marked on the board, and these weights will represent the load which must be placed over the centre of gravity of each of the voussoirs, as shown by the dotted lines, in order that the arch may be in equilibrium.

To find what will be the thrust at the abutments, or at any point in the arch, draw *a c*, touching the curve, the vertical line *a b* of any convenient length, and the horizontal line *b c*, then the lengths of the lines *a c*, *a b*, and *b c*, will be respectively as the thrust of the arch at *a*, in the direction *a c*, and the vertical pressure and horizontal thrust into which it is resolved ; and the weight of that part of the arch between its centre and the point *a*, which is represented by *a b*, being known, the other forces are readily calculated from it.

50. When the form of an arch does not exactly coincide with its curve of equal horizontal thrust, there will always be some minimum thickness necessary to contain this curve, and to insure the stability of the arch. In a semicircular arch, fig. 22, whose thickness is $\frac{1}{9}$th of its radius, the line of equal horizontal thrust just touches the extrados at the crown, and the intrados at the haunches, pointing out the places where failure would take place with a less thickness or an unequal load by the voussoirs turning on their edges. Those arches which differ most from their curves of equal horizontal thrust are semicircles and semi-ellipses, which have a tendency to descend at their crowns and to rise at their haunches, unless they are well *backed up*. Pointed

arches have a tendency to *rise* at the crown; and, to prevent this, the cross springers of the ribbed vaults of the middle

Fig. 22.



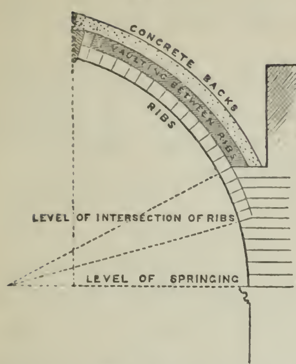
ages were often made of a semicircular profile, their flatness at the crown being concealed by the bosses at their intersections.

51. If the experiment be tried of equilibrating, in the manner above described, a suspended semicircular or semi-elliptical arch, it will be found to be practically impossible, as the weight required for that purpose becomes infinite at the springing. This difficulty does not exist in practice, for that part of an arch which lies beyond the plane of the face of the abutment in reality forms a part of the abutment itself (fig. 22).

The Gothic architects well understood this, and in their vaulted roofs built this portion in horizontal courses as part of the side walls (fig. 23), commencing the real arch at a point considerably above the springing.

52. The depth of the voussoirs in any arch must be sufficient to contain the curve of equilibrium under the greatest load to which it can be exposed; and, as the pressure on the arch stones increases from the crown to the springing, their depth should be increased in the same proportion. Each joint of the voussoirs should be at right angles to a tangent to the curve of equilibrium at the point through which it passes

Fig. 23.*



53. *Brick Arches.*—In building arches with bricks of the common shape, which are of the same thickness throughout their length, a difficulty arises from the thickness of the mortar joints at the extrados being greater than at the intrados, thus causing settlement and sometimes total failure. To obviate this difficulty, it is usual to build brick arches in separate rings of the thickness of half a brick, having no connection with each other beyond the adhesion of the mortar or cement, except an occasional course of headers where the joints of two rings happen to coincide. There is, however, a strong objection to this plan, viz. that, if the curve of equal horizontal thrust do not coincide with the curvature of the arch, the line of pressure will cross the rings, and cause them to separate from each other.

54. The preferable plan will be, therefore, to bond the brickwork throughout the whole thickness of the arch, using either cement or hard-setting mortar, which will render the thickness of the joints of comparatively little importance.

Cement, however, is not so well suited for this purpose as the hard-setting mortars made from the Lias limes, because it sets before the work can be completed; and in case of any settlement, however trifling, taking place on the striking of the centres, the work becomes crippled. It is therefore preferable to use some hard-setting mortar, which does not, however, set so quickly as cement, thus allowing

* This diagram is slightly altered from one of the illustrations to Professor Willis's paper "On the Construction of the Vaults of the Middle Ages," in the Transactions of the Royal Institute of British Architects, Vol. I., Part 2.

the arch to adjust itself to its load, or, in technical language, to *take its bearing*, before the mortar becomes perfectly hard.

55. We have in the preceding remarks considered an equilibrated arch as a curved beam, every part of which is in a state of compression; and, in an arch composed of stone voussoirs, this is practically the case.

We may, however, by the employment of other materials, as cast iron and timber, construct arches whose forms differ very materially from their curves of equal horizontal thrust.

Thus the semicircular arch (fig. 22), which, if built of stone voussoirs small in proportion to the span of the arch, would fail by the opening of the joints at *a* and *b*, might be safely constructed with cast iron ribs, with the joints placed at *c* and *d*, the metal at the points *a* and *b* being exposed to a cross strain precisely similar to that of a horizontal beam loaded in the centre.

56. Laminated arched beams, formed of planks bent round a mould to the required curve and bolted together, have been extensively used in railway bridges of large span during the last ten years, and from their comparative elasticity, and the resistance they offer to both tension and compression, are very well adapted to structures of this kind, which have to sustain very heavy loads passing with great rapidity over them.

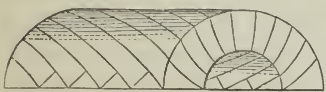
It is to be regretted, however, that the perishable nature of the material does not warrant their long duration, notwithstanding every precaution that can be taken for the preservation of the timber.

57. *Skew Arches.*—In ordinary cases the plan of an arch is rectangular, the faces of the abutments being at right angles to the fronts; but of late years the necessity which has arisen on railway works for carrying communications across each other without regard to the angle of their intersection has led to the construction of oblique or *skew* arches.

58. In an ordinary rectangular arch each course is parallel to the abutments, and the inclination of any bed joint with the horizon will be the same at every part of it

In a skew arch it is not possible to lay the courses parallel to the abutments, for, were this done, the thrust being at right angles to the direction of the courses, a great portion of the arch on each side would have nothing to keep it from falling. In order to bring the thrust into the right direction, the courses must therefore be laid as nearly as possible at right angles to the fronts of the arch (see fig. 24), and at an angle with the abutments; and it is this which produces the peculiarity of the skew arch. The two ends of any course will then be at different heights, and the inclination of each bed joint with the horizon will increase from the springing to the crown, causing the beds to be *winding* surfaces instead of a series of planes as in a rectangular arch. The variation in the inclination of the bed joints is called the *twist* of the beds, and leads to many difficult problems in stone-cutting, the consideration of which would be unsuited to the elementary character of this little work.

Fig. 24.



The reader who wishes to pursue the subject is referred to the volume of this series "On Masonry and Stone-cutting."

59. *Centering.*—The *centering* of an arch is the temporary framework which supports it during its erection, and is formed of a number of ribs or *centres*, on which are placed the planks or *laggings* on which the work is built.

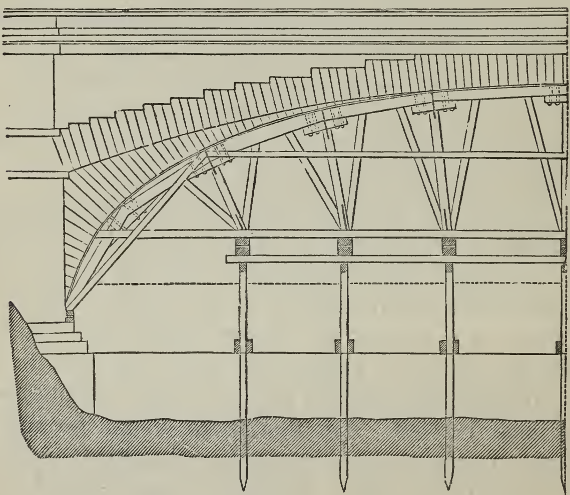
60. In designing centres, there are three essential points to be kept in view. 1st, that there should be sufficient strength to prevent any settlement or change of form during the erection of the arch. 2nd, that means should be provided for *easing* or lowering the centre gradually from under any part of the arch. 3rd, that, as the construction of centres generally involves the use of a large quantity of timber merely for a temporary purpose, all unnecessary injury to it should be avoided, in order that its value for subsequent use may be as little diminished as possible.

61. Fig. 25 represents the construction of the centering

used in the erection of the Gloucester Over Bridge, designed by Mr. Cargill, the contractor, which fulfils the above-named conditions in a very perfect manner: by means of the *striking wedges* under the radiating struts, any part of these centres can be lowered at pleasure, and, from the position of the struts, there is no tendency to alteration in the curve from undue pressure on the haunches during the erection of the arch. (See Note B, p. 155.)

62. Centering on the same principle as the above was made use of in the erection of the Grosvenor Bridge at Chester, by Mr. Trubshaw, the contractor for that work. Instead of the centres being made to rest on the striking

Fig. 25.



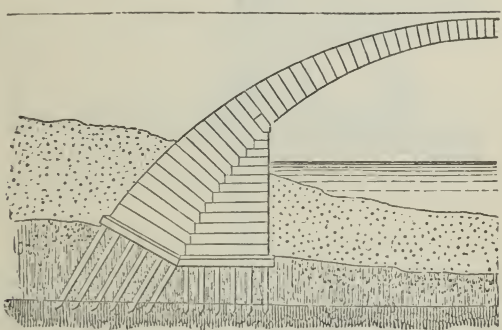
wedges, however, as in the centering for the Gloucester Bridge, the wedges were placed under the laggings themselves, by which means the arch could be eased in the most gradual manner.

63. Where the circumstances of the case do not admit of piles or other supports being placed between the piers, it becomes necessary to construct a trussed framing resting

on the piers, and of sufficient strength to support the weight of the arch. The tendency of this form of centre to rise at the crown, from the great pressure thrown upon the haunches during the erection of the arch, renders it necessary to weight the crowns with blocks of stone until it is nearly completed. Centres of this kind are always costly, afford less facilities for easing, and are in every way inferior to those we have described as used at Gloucester and Chester.

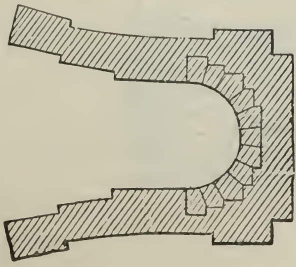
64. *Abutments.*—The tendency of any arch to overturn its abutments, or to destroy them by causing the courses to

Fig. 26.



slide over each other, may be counteracted in three ways 1st, the arch may be continued through the abutment until it rests on a solid foundation, as in fig. 26 2nd, by build-

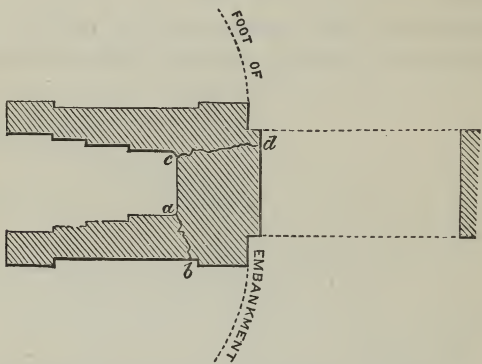
Fig. 27.



ing the abutments so as to form a horizontal arch, the thrust being thrown on the wing walls, which act as buttresses (fig. 27). 3rd, where neither of these expedients is practicable, by joggling the courses together with bed-dowel joggles, so as to render the whole abutment one solid mass (fig. 36).

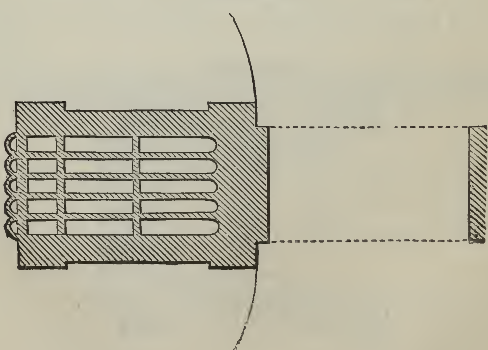
65. *Wing Walls.*—Where the wing walls of a bridge are

Fig. 28.



built as shown in fig. 28, the pressure of the earth will always have a tendency to fracture them at their junction with the abutments, as shown by the lines *a b*, *c d*. Equal

Fig. 29.



strength with the same amount of material will be obtained by building a number of thin longitudinal and cross walls, as shown in fig. 29, by which means, the earth being kept from the back of the walls, there is no tendency to failure of this kind.

66. *Vaulting.*—The ordinary forms of vaults may be classed under three heads, viz. *cylindrical*, *coved*, and *groined*.

A *cylindrical* vault is simply a semicircular arch, the ends of which are closed by upright walls, as shown in fig. 30. When a vault springs from all the sides of its plan, as in fig. 31, it is said to be *coved*. When two cylindrical vaults intersect each other, as in fig. 32, the intersections of the

Fig. 30.

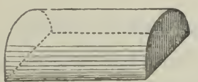
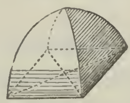


Fig. 31.

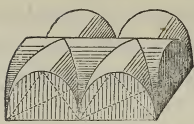


vaulting surfaces are called *groins*, and the vault is said to be *groined*.

67. In the Roman style of architecture, and in all common vaulting, the vaulting surfaces of the several compartments are portions of a continuous cylindrical surface, and the profile of a groin is simply an oblique section of a semi-cylinder.

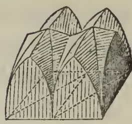
68. Gothic ribbed vaulting is, however, constructed on a totally different principle. It consists of a framework of light stone ribs supporting thin pannels, whence this mode of construction has obtained the name of *rib and pannel* vaulting. The curvature of the diagonal ribs or cross springers, and of the intermediate ribs, is not governed in any way by the form of the transverse section of the vault, and in this consists the peculiarity of ribbed vaulting. This will be understood by a comparison of figs. 32 and 33. For a description of the several varieties of Gothic vaults, and the modes of tracing the curves of the ribs, the reader is referred to the volume of this series on "Masonry and Stone-cutting."

Fig. 32.



Roman vaulting.

Fig. 33.



Gothic vaulting.

69. Domes are vaults on a circular plan. The equilibrium of a dome depends on the same conditions as that of a common arch, but with this difference, that, although a dome may give way by the weight of the crown forcing out the haunches, failure by the weight of the haunches squeezing up the crown is impossible, on account of the support the voussoirs of each course receive from each other.

MASONRY—BRICKWORK—BOND.

70. The term *masonry* is sometimes applied generally to all cemented constructions, whether built of brick or stone; but in England the use of the term is confined exclusively to stone-work.

71. There are many kinds of masonry, each of which is known by some technical term expressive of the manner in which the stone is worked; but they may all be divided under three heads.

1st. Rubble work (fig. 34), in which the stones are used without being squared

2nd. Coursed work (fig. 35), in which the stones are squared, more or less, sorted into sizes, and ranged in courses.

Fig. 34.

Fig. 35.

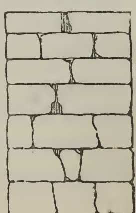
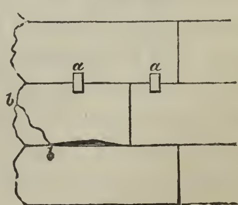


Fig. 36.



3rd. Ashlar work* (fig. 36), in which each stone is squared and dressed to given dimensions.

72. Different kinds of masonry are often united. Thus a wall may be built with ashlar facing and rubble backing; and there are many gradations from one class of masonry to another, as *coursed rubble*, which is an intermediate step between rubble work and coursed work.

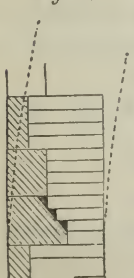
73. In ashlar masonry, the stability of the work is independent, in ordinary cases, of the adhesion of the mortar. Rubble work, on the contrary, depends for support in a great measure upon it.

74. In dressing the beds of ashlar work, care must be taken not to work them hollow, so as to throw the pressure upon the edges of the stones, as this leads to unsightly fractures, as *b b*, fig. 36.

75. Where there is a tendency of the courses to slide on each other from any lateral pressure, it may be prevented by bed-dowel joggles, as shown at *a a*, fig. 36

76 Where the facing and the backing of a wall do not contain the same number of courses, as in the case of a brick wall with stone facings (fig. 37), the work will be liable to settle on the inside, as shown by the dotted lines, from the greater number of mortar joints. The only way of preventing this is to set the backing in cement, or some hard and quick-setting mortar.

Fig. 37.



77. In facing brickwork with stone ashlar, the stones should be all truly squared, and worked to sizes that will bond with the brickwork. If this be neglected, there will be numerous vacuities in the thickness of the wall (see fig. 37), and the facing and backing will have a tendency to separate.

78. *Bond*, in masonry, consists in the placing of the stones in such relative positions that no joint in any course shall be in the same plane with any

* In London the term "ashlar" is commonly applied to a thin facing of stone placed in front of brickwork.

other joint in the course immediately above or below it. This is called *breaking joint*

79. Stones placed lengthwise in any work are called *stretchers*, and those placed in a contrary direction are called *headers*. When a header extends throughout the whole thickness of a wall, it is called a *through*.

Fig. 38.

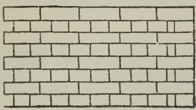
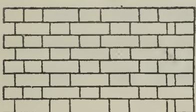


Fig. 39.



79. There are two kinds of bond made use of by bricklayers, called respectively *English bond* and *Flemish bond*. In the first the courses are laid alternately with headers and stretchers (fig. 38); in the second, the headers and stretchers alternate in the same course (fig. 39). This is considered to have the neatest appearance: but, as the number of headers required is fewer than in English bond, there is not so much lateral tie, and on this account it is considered to be much inferior to it in strength. A common practice, which cannot be too much reprobated, is that of building brick walls with two qualities of bricks, without any bond between them, the headers of the facing bricks being cut in two to save the better material, thus leaving an upright joint between the facing and backing.

80. In building upright walls which have to sustain a vertical pressure, three leading principles must be kept in view.

1. Uniformity of construction throughout the whole thickness.
2. The bonding of the work together.
3. The proper distribution of the load.

81 *Uniformity of Construction.*—We have already spoken of the danger arising from the backing of a wall containing more compressible material than the facing; but it cannot be too often repeated, that in all building operations it is not the *amount*, but the *irregularity* of settlement which is so dangerous. Thus a rubble wall, with proper care, may

be carried up to a great height, and bear safely the weight of the floors and roof of a large building, whilst a wall built of bricks and mortar, and faced with dressed ashlar, will, under similar circumstances, be fractured from top to bottom, from the difference in settlement of the facing and backing.

It is a common but vicious practice to build the ends of joists and other timbers into the walls, and to rest the superincumbent work upon them. This is liable to lead to settlements from the shrinking of the timber, and should always be guarded against by leaving proper recesses for the ends of the timbers, so that the strength of the masonry or brickwork shall be quite independent of any support from them.

82. *Bond.*—In addition to the bonding together of the materials above described, a further security against irregular settlement is usually provided for brick walls, in the shape of ties of timber, called *bond*, which are cut of the depth and thickness of a brick, and built into the work. There is, however, a great objection to the use of timber in the construction of a wall, as it shrinks away from the rest of the work, and often endangers its stability by rotting.

83. Instead of bond timbers, hoop-iron bond is now very generally used. This is formed of iron hooping, tarred, to protect the iron from contact with the mortar, and laid in the thickness of the mortar joints. This forms a very perfect longitudinal tie, and has all the advantages, with none of the disadvantages, of bond timbers.

84. *Distribution of the Load.*—It is always advisable, when a heavy load has to be supported on a few points, as in the case of a large floor resting on girders, to bring the weight as nearly as possible on the centre of the wall, and to distribute it over a large bearing surface, by stone bonding through its whole thickness; this arrangement is shown in figures 40 and 41.

85. It is of importance in designing buildings to arrange the apertures for doors, windows, &c., in the different floors,

so that openings shall be over openings, and piers over piers; if this be not attended to, it is scarcely possible to

Fig. 40.

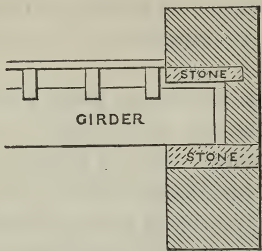


Fig. 41.

prevent settlements In addition to this, as the pressure on the foundations will be greatest under the piers, it is desirable to connect these with inverted arches, by which means the weight is distributed equally over the whole surface of the foundations.

86. All openings in walls for doors, windows, gateways, &c., should be arched over throughout the whole thickness of the walls in which they occur; and wooden lintels and bressummers should only be introduced as ties to counteract the thrust of the arches, and as attachments for the internal finishings.

87. Bressummers of cast iron are often used for supporting the walls of houses over large openings, as in the case of shop fronts; but they have the disadvantage of being liable to be cracked, in case of fire, if water is thrown on them whilst in a heated state, which renders their use very objectionable, as no dependence can be placed upon them after having been suddenly cooled in this manner, even if they do not actually break at the time.

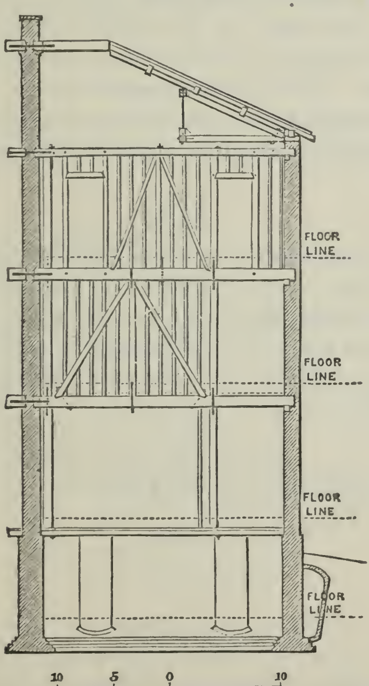
PARTITIONS.

88. The partitions forming the interior divisions of a building may be either solid walling of brick or stone, or they may be constructed entirely of timber, or they may be frames of timber filled in with masonry or brickwork.

It will always be best, both for durability and security against fire, to make the partitions of solid walling; but this is not always practicable, and, in the erection of dwelling houses, they are for the most part made of timber.

The principles to be kept in view in the construction of framed timber partitions are very simple. Care must be taken to avoid any settlement from cross strain, and they should not in any way depend for support upon subordinate parts of the construction, but should form a portion of the

Fig. 42.



main carcase of the building, and be quite independent of the floors, which should not support, but should be supported by them.

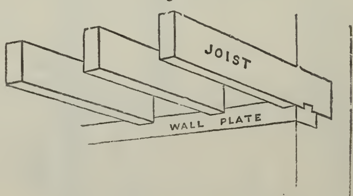
Where a partition extends through two or more stories of a building, it should be as much as possible a continuous piece of framing, with strong sills at proper heights to support the floor joists.

Where openings occur, as for folding doors, or where a partition rests on the ends of the sill only, it should be strongly trussed, so that it is as incapable of settlement as the walls themselves. From want of attention to these points, we frequently see in dwelling-houses floors which have sunk into curved lines, doors out of square, cracked ceilings and broken cornices, and gutters that only serve to conduct the roof water to the interior of the building, to the injury of ceilings and walls, and the great discomfort of its inmates. The above remarks will be better understood by a study of fig. 42, which is an example of a framed partition extending through three stories of a dwelling house.

FLOORS.

89. The assemblage of timbers forming any *naked flooring* may be either *single* or *double.* Single flooring is formed with joists reaching from wall to wall, where they rest on *plates* of timber built into the brickwork, as in fig. 43. The floor boards are nailed over the upper edges of the joists,

Fig. 43.

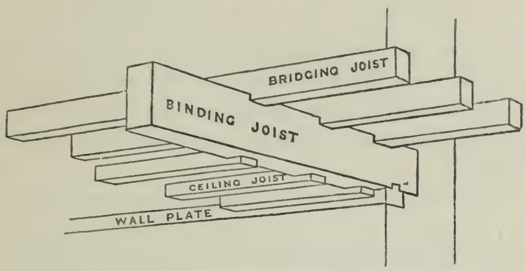


Single flooring.

whose lower edges receive the lathing and plastering of the ceilings. Double floors are constructed with stout *binding joists*, a few feet apart, reaching from wall to wall, and supporting *ceiling joists* which carry the ceiling; and *bridging joists*, on which are nailed the floor boards (fig. 44).

In *double-framed flooring*, the binders, instead of resting in the walls, are supported on *girders*, as shown in fig. 45

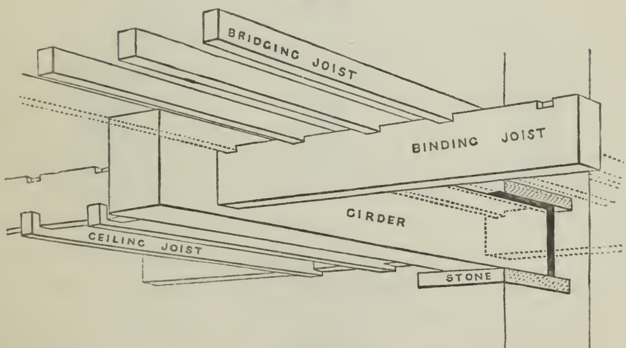
Fig 44.



Double flooring.

Single flooring is, in many respects, inferior to double flooring, being liable to *sag*, or deflect, so as to make the

Fig. 45.



Double-framed flooring.

floor concave, and the vibration of the joists occasions injury to the ceilings, and also shakes the walls. In double flooring the stiffness of the binders and girders prevents both deflection and vibration, and the floors and ceilings *hold their lines*, that is, retain their intended form much better than in single flooring.

90 The joists in a single floor are usually laid on a plate

built into the wall, as shown in fig. 43; it is, however, preferable to rest the plate on projecting corbels, which prevents the wall being crippled in any way, by the insertion of the joists. The plates of basement floors are best supported on small piers carried up from the footings. This is an important point to be attended to, as the introduction of timber into a wall is nowhere likely to be productive of such injurious effects as at the foundations, where, from damp and imperfect ventilation, all wood-work is liable to speedy decay.

The ends of all girders should rest in recesses, formed as shown in figs. 40 and 41, and with a space for the free circulation of air round the timber, which is one of the best preventives of decay.

The manner in which ceiling joists and bridging joists are framed to the binders, and these latter tenoned into the girders, is shown in figs. 46, 47, 48, and 49.

Fig. 46.

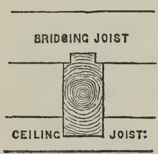


Fig. 47.

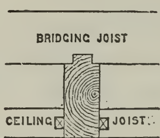


Fig. 48.

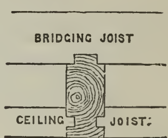
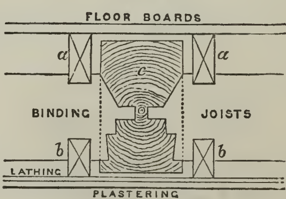


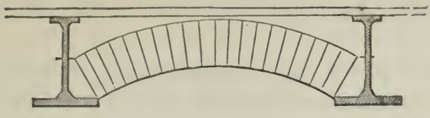
Fig. 49.



a a, bridging joists; *b b*, ceiling joists; *c*, girder.

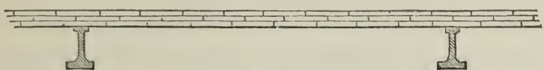
91. Fire-proof floors are usually constructed with iron girders a short distance apart, which serve as abutments for a series of brick arches, on which either a wooden or plaster floor may be laid (see fig. 50). (See Note C, p. 156.)

Fig. 50.



92. Of late years many terraces and flat roofs have been constructed with two or more courses of plain tiles, set in cement, and breaking joint with each other, supported at short intervals by cast-iron bearers, as shown in fig. 51 This mode of construction, although appearing very slight,

Fig. 51.



possesses great strength, and is now very much used in and about London.

ROOFING.

93. In roofs of the ordinary construction, the roof covering is laid upon *rafters* supported by horizontal *purlins*, which rest on upright *trusses* or frames of timber, placed on the walls at regular distances from each other. Upon the framing of the trusses depends the stability of the roof, the arrangement of the rafters and purlins being subordinate matters of detail. The timbering of a roof may be compared to that of a double-framed floor, the trusses of the former corresponding to the girders of the latter, the purlins to the binders, and the rafters to the joists.

Timber roofs may be divided under two heads—

1st. Those which exert merely a vertical pressure on the walls on which they rest.

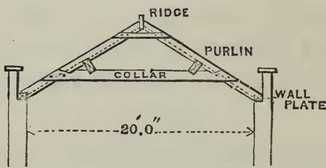
2nd. Those in which advantage is taken of the strength of the walls to resist a side thrust, as in many of the Gothic open timbered roofs.

94. *Trussed Roofs, exerting no Side Thrust on the Walls.*—In roofs of this kind each truss consists essentially of a pair of principal rafters or *principals*, and a horizontal *tie*

beam, and in large roofs these are connected and strengthened by *king and queen posts* and *struts* (see figs. 53 and 54).

Fig. 52 shows a very simple truss in which the tie is above the bottom of the feet of the principals, which is

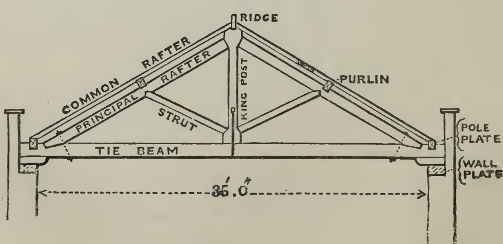
Fig. 52.



often done in small roofs for the sake of obtaining height. The tie in this case is called a *collar.* The feet of both common and principal rafters rest on a *wall plate.* The purlins rest on the collar, and the common rafters but against a *ridge* running along the top of the roof. This kind of truss is only suited to very small spans, as there is a cross strain on that part of the principals below the collar which is rendered harmless in a small span by the extra strength of the principals, but which in a large one would be very likely to thrust out the walls.

95 In roofs of larger span the tie beam is placed below the feet of the principals, which are tenoned into, and bolted to it. To keep the beam from *sagging*, or bending by its own weight, it is suspended from the head of the

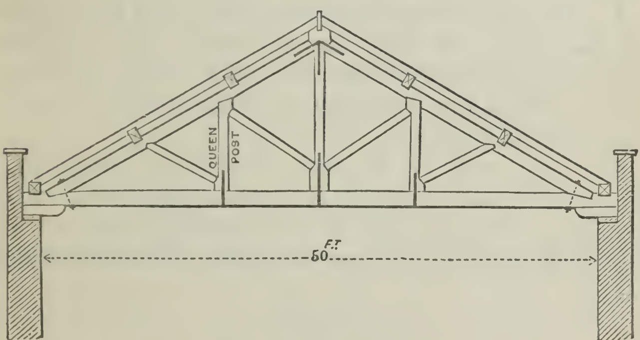
Fig. 53.



principals by a king post of wood or iron. The lower part of the king post affords abutments for struts supporting the principals immediately under the purlins, so that no cross strain is exerted on any of the timbers in the truss, but they all act in the direction of their length, the principals and struts being subjected to compression, and the king post and tie beam to tension. Fig. 53 shows a sketch of a king truss. The common rafters but on a *pole plate*, the tie beams resting either on a continuous plate, or on short templates of wood or stone.

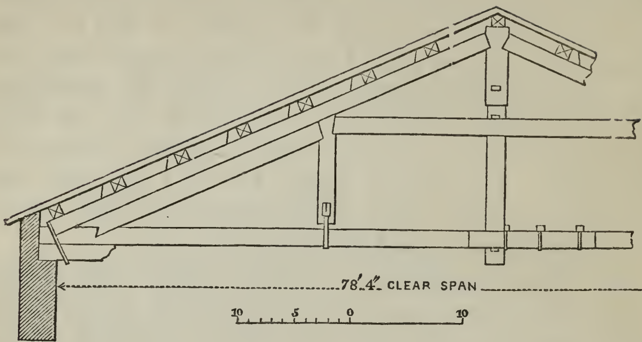
96. Where the span is considerable, the tie beam is supported at additional points by suspension pieces called queen posts (fig. 54), from the bottom of which spring

Fig. 54.



additional struts ; and, by extending this principle *ad infinitum*, we might construct a roof of any span, were it not that a practical limit is imposed by the nature of the materials. Sometimes roofs are constructed without king posts, the queen posts being kept apart by a straining piece. This construction is shown in fig. 55, which shows the design of the old roof (now destroyed) of the church of St. Paul, outside the walls, at Rome. This truss is interesting from its early date, having been erected about 400 years ago; the trusses are in pairs, a king post being keyed

Fig. 55.

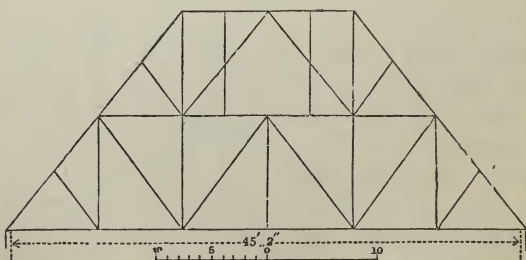


in between each pair to support the tie beams in the centre.

97. Of late years iron has been much used as a material for the trusses of roofs, the tie beams and suspending pieces being formed of light rods, and the principals and struts of rolled T or angle iron, to which sockets are riveted to receive the purlins.

The iron roofs of the new Houses of Parliament at Westminster are admirable examples of this mode of construction. The principle of the trussing of the roof over the House of Peers is shown in fig. 56. The tie beam and

Fig. 56.

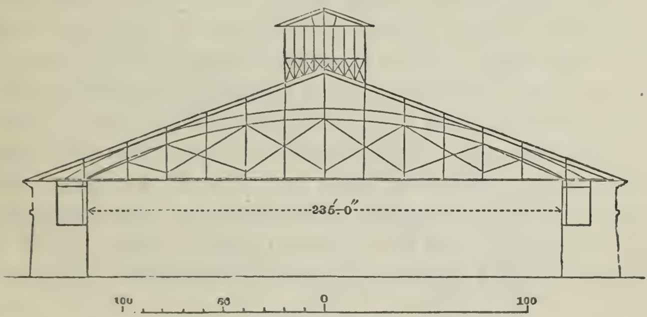


suspension rods are of flat bar iron, the principal and common rafters are of rolled T iron, the struts and purlins

are of cast iron, and the whole is fitted together with cast-iron shoes.

98. The great novelty in the construction of the roofs just mentioned consists in their covering, which is formed of galvanized sheets of cast iron, lapping over each other at the joints, and forming a very perfect and water-tight covering, which is at the same time perfectly fire-proof,

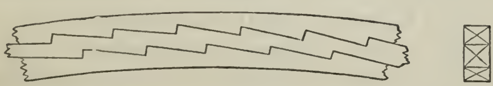
Fig. 57.



and not liable to be affected by exposure to the atmosphere.

99. The largest roof ever executed in one span is that of the Imperial Riding-House at Moscow, built in 1790, of which the span is 235 ft. (fig. 57). The principal feature in this roof is an arched beam, the ends of which are kept from spreading by a tie beam, the two being firmly connected by suspension pieces and diagonal braces: the arched beam (fig. 58) is formed of three thicknesses of

Fig. 58.

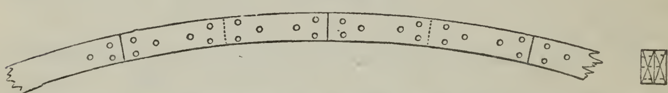


timber, notched out to prevent their sliding on each other, — a method which is objectionable on account of the danger of the splitting of the timber under a considerable strain. (See Note D, p. 156.)

100. The principle of the *bow suspension truss*, as this system of trussing is called, has been much used within the last ten years for railway bridges and similar works. One of the best executed works of this kind is a bridge over the River Ouse, near Downham Market, in Norfolk, on the line of the Lynn and Ely Railway, the trusses of which are 120 ft. span.

101. *Roofs on the principle of the Arch.*—In the 16th century, Philibert de Lorme, a celebrated French architect, published a work in which he proposed to construct roofs and domes with a series of arched timber ribs in place of trusses, these ribs being formed of planks in short lengths, placed edgewise, and bolted together in thicknesses, breaking joint (fig. 59). This mode of construction has been more or less used ever since the time of its author. An instance of its successful application on a large scale was the original dome of the Halle au Blé, at Paris, 120 ft. in diameter, built by Messrs. Legrand and Molino. This roof

Fig. 59.



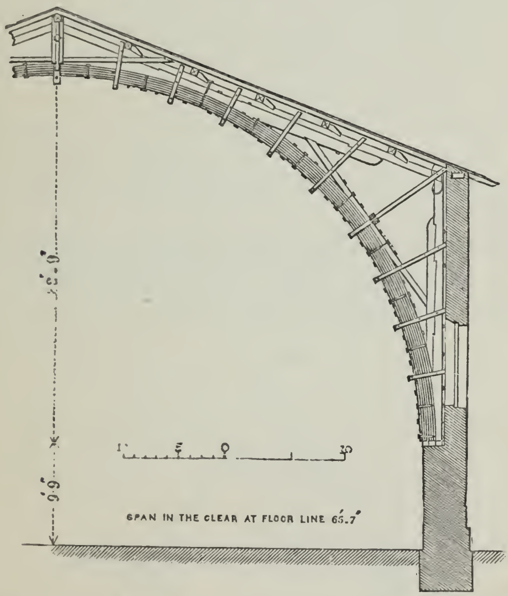
has since been replaced by an iron one, the original dome having been destroyed by fire.

The roof of the central compartment of the Pantheon Bazaar in Oxford Street, London, 38 ft. span, is another very elegant example.

102. There are, however, some great disadvantages connected with this system. There is considerable waste of material; the labour is great as compared with roofs of similar span of the ordinary construction; and, as the chief strength of the rib depends upon the lateral cohesion of the fibres of the wood, it is necessary to provide such an amount of surplus strength as shall insure it against the greatest cross strain to which it can be exposed from violent winds or otherwise

103. Struck by these disadvantages, Colonel Emy, a French military engineer, proposed, in 1817, an improvement on the system of Philibert de Lorme, which was precisely the laminated arched rib so much in use at the present day. It was not until 1825 that he obtained permission to put his design into execution in the erection of a large roof 65 ft. span at Marac, near Bayonne (fig. 60).

Fig. 60.



The ribs in this roof are formed of planks bent round on templets to the proper curve, and kept from separating by iron straps, and also by the radiating struts which are in pairs, notched out so as to clip the rib between them.

The principle of the roof is exceedingly good. The principals, wall-posts, and arched rib, form two triangles, firmly braced together, and exerting no *thrust* on the walls; and the weight of the whole roof being thrown on the walls at the feet of the ribs, and not at the pole plate, the

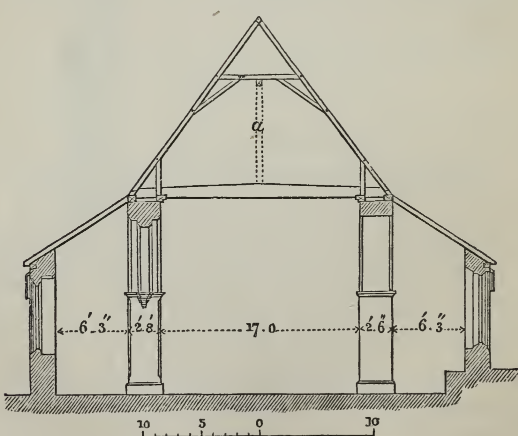
walls are not tried by the action of a heavy roof, and the consequent saving in masonry is very great.*

The great difference in principle between the arched rib of Philibert de Lorme, and the laminated rib of Colonel Emy, is, that in the latter the direction of the fibre of the wood coincides with the curvature of the rib; and, as a consequence of this, the joints are much fewer; the rib possesses considerable elasticity, so as slightly to yield rather than break under any violent strain; and, from the manner in which the planks are bolted together, it is impossible for the rib to give way, unless the force applied be sufficient to crush the fibres.

The principle of the laminated arched rib was first applied in England in 1837 by the Messrs. Green of Newcastle, by whom it has been extensively used in the erection of railway bridges.

104. *Gothic Roofs.*—The open timber roofs of the middle ages come, for the most part, under the second class, viz. those which exert more or less thrust upon the walls, al-

Fig. 61.



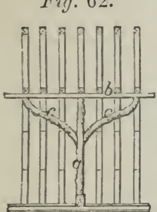
* See Tredgold's Carpentry, new and much improved edition, in 4to. 1853.

though there are many fine examples in which this is not the case.

We propose to describe the principal varieties of these roofs, without reference either to their decorative details, or to their chronological arrangement, our object here being simply to explain the principles on which they were constructed.

105. Fig. 61, which is a section of the parish church of Chaldon, near Merstham in Surrey, shows a system of roofing formerly very common. This may be compared to single flooring, as there are no principals, purlins, or even ridge. It is a defective form of roof, as the rafters have a tendency to spread and thrust out the walls. In the example before us, this effect has been prevented by the insertion of tie beams, from which the collars have been propped up (fig. 62), thus, in fact, balancing the roof on the centres of the collars, which are in consequence violently strained.

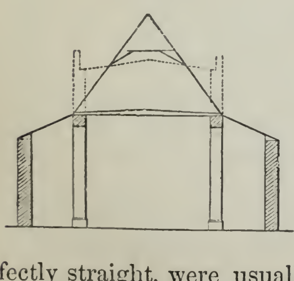
Fig. 62.



a post; *b* sill; *c c* struts.

106. After the introduction of the 4-centred arch, a great many church roofs of the construction just described were altered, as shown by the dotted lines in fig. 63, in order to obtain more light by the introduction of clerestory windows over the nave arches. The flat roofs which superseded the former ones were often formed without any truss whatever, being simply an arrangement of main beams, purlins, and rafters, precisely similar to a double-framed floor, with the difference only that the main beams, instead of being perfectly straight, were usually cut out of crooked timber so as to divide the roof into two inclined planes.

Fig. 63.



To throw the weight of the roof as low down as possible,

the ends of the main beams are often supported on upright posts placed against the walls and resting on projecting corbels, the wall posts and beams being connected by struts in such a way that deflection in the centre of the beam cannot take place, unless the load be sufficient to force out the walls, as shown by the dotted lines in fig. 64. The struts are often cut out of stout plank, forming solid spandrils, the edges of which are moulded to suit the profile of the main beam (see fig. 65), which also

Fig. 64.

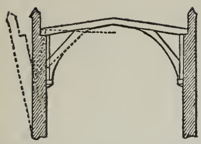
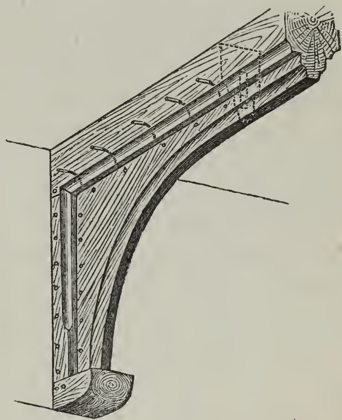


Fig. 65.



shows the manner of securing the struts to the wall posts and to the beam with *tongues* and wooden pins. A very good example of this construction is shown in fig. 66, which is from West Bridgeford Church, Nottinghamshire. There are many very beautiful examples remaining in different parts of the country.

107. A somewhat similar construction to that last described is shown in fig. 67, in which principals are introduced, strutted up from the main beam, so as to give a greater slope to the roof than could well be obtained with a single beam.

Fig. 66.

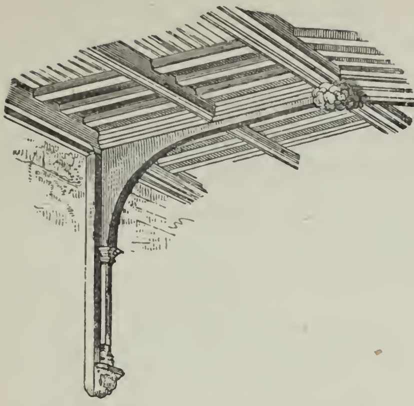


Fig. 67.

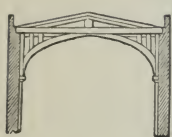
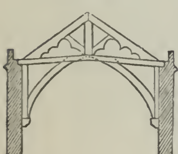


Fig. 68.



108. Fig. 68 exhibits a construction often to be met with, which, in general appearance, resembles a trussed king post roof, but which is in reality very different, the tie beam being a strong girder supporting the king post, which, instead of serving to suspend the tie beam from the principals, is a prop to the latter. In this and the previous example, any tending to deflection of the tie beam is prevented by struts: the weight of the roof is thrown by means of wall posts considerably below the feet of the rafters, so that the weight of the upper part of the wall is made available to resist the thrust of the struts.

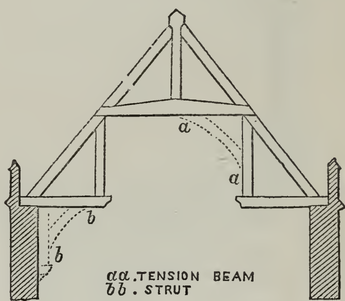
109 The roofs we have been describing are not to be recommended as displaying any great amount of constructive skill. Indeed, although they answer very well for small spans with timbers of large scantling and side walls of sufficient thickness to resist a considerable thrust, they are totally unsuited to large spans, and are in every way inferior to trussed roofs.

The above remarks do not apply to the high pitched

roofs of the large halls of the fifteenth and sixteenth centuries, which, for the most part, are trussed in a very perfect manner, so as to exert no thrust upon the walls; although, in some instances, as at Westminster Hall, they depend upon the latter for support.

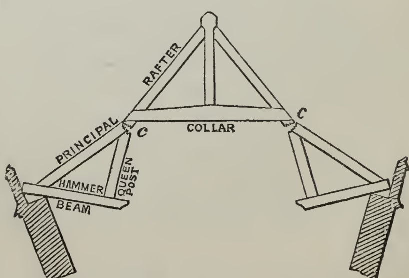
The general design of these roofs is shown in figs. 69 and 70. The essential parts of each truss are, a pair of

Fig. 69.



principals connected by a collar or *wind beam*, and two *hammer beams*, with queen posts over them, the whole forming three triangles, which, if not secured in their relative positions, otherwise than by the mere transverse strength of the principals, would turn on the points *c c* (fig. 70), the weight of the roof thrusting out the walls in the manner shown in the figure. There are two ways in which

Fig. 70.

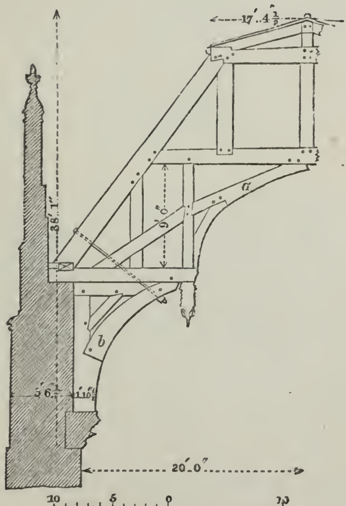


a truss of this kind may be prevented from spreading. 1st. The ends of the hammer beams may be connected with the collar by tension pieces, *a a* (fig. 69), by which the thrust on the walls will be converted into a vertical pressure. 2nd. The hammer beams may be kept in their places by struts, *b b*, the walls being made sufficiently strong by buttresses, or otherwise, to resist the thrust.

In existing examples, we find sometimes one and sometimes the other of these plans followed; and occasionally both methods are combined in such a manner that it is often difficult to say what parts are in a state of compression, and what are in a state of tension.

110. The roof of the great hall at Hampton Court (fig. 71) is very strong, and so securely tied, that were the bottom

Fig. 71.

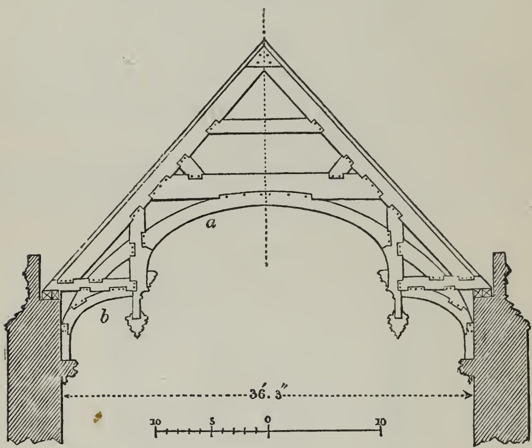


struts, *b b*, removed, there would be little danger of the principals thrusting out the walls; and, on the other hand, from the weight of the roof being carried down to a considerable distance below the hammer beams by the wall

posts, the walls themselves offer so much resistance to side thrust, that there would be no injurious strain on them were the tension pieces, *a a*, removed.

111. The construction of the roof of the hall at Eltham Palace, Kent (fig. 72), differs very considerably from that of

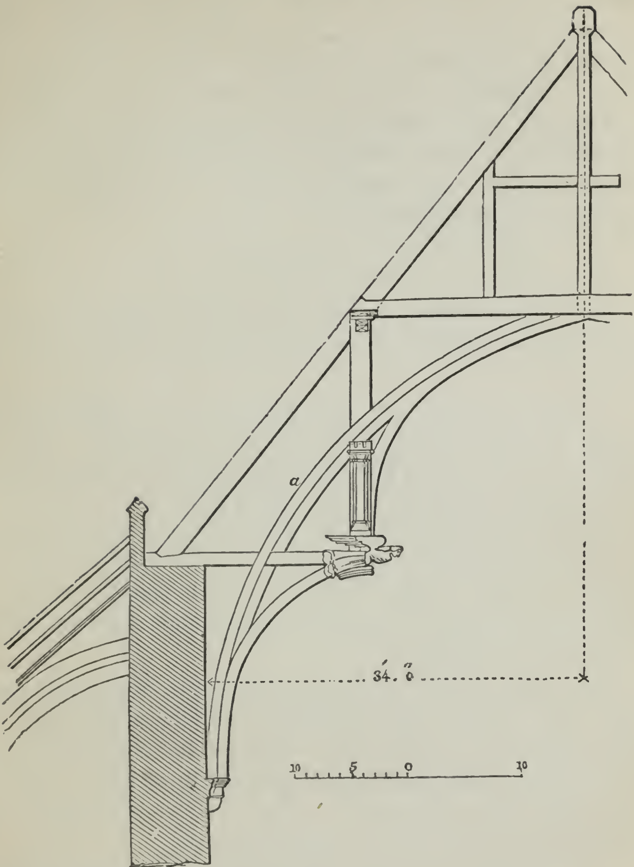
Fig. 72.



the Hampton Court roof. The whole weight is thrown on the top of the wall, and the bottom pieces, *b b*, are merely ornamental, the tension pieces, *a a*, forming a complete tie. This has been shown by a partial failure which has taken place. The wall plates having become rotten in consequence of the gutters being stripped of their lead, the weight has been thrown on the pseudo struts, which have bent under the pressure, and forced out the upper portion of the walls.

112. The roof of Westminster Hall (fig. 73) is one of the finest examples now existing of open timbered roofs. The peculiar feature of this roof is an arched rib in three thicknesses, something on the principle of Philibert de Lorme; but it is so slight, compared with the great span, that it is probable in designing the roof, the architect took

Fig. 73.



full advantage of the support afforded by the thickness of the walls and the buttresses ; if, indeed, the latter were not added at the time the present roof was erected, in 1395. It has been ascertained that the weight of the roof rests on the top of the walls, the lower part of the arched rib only serving to distribute the thrust, and to assist in preventing the hammer beams from sliding on the walls.

113. The mediæval architects generally employed oak in the construction of their large roofs, the timbers being morticed and pinned together, as shown in fig. 65. This system of construction is impossible in fir and other soft woods, in which the fibres have little lateral cohesion, as the timber would split with the strain; and therefore, in modern practice, it is usual to secure the connections with iron straps or bolts passing round or through the whole thickness of the timbers.

ROOF COVERINGS.

114. The different varieties of roof coverings principally used may be classed under three heads: stone, wood, and metal.

Of the first class, the best kind is slate, which is used either sawn into slabs or split into thin laminæ. The different sizes of roofing slate in common use are given in the description of Slaters' Work, article 234.

In many parts of the country thin slabs of stone are used in the same way as roofing slate. In the Weald of Sussex the stone found in the locality is much used for this purpose, but it makes a heavy covering, and requires strong timbers to support it.

115. *Tiles* are of two kinds: *plain tiles*, which are quite flat; and *pantiles*, which are of a curved shape, and lap over each other at the sides. Each tile has a projecting ear on its upper edge, by which it is kept in its place. Sometimes plain tiles are pierced with two holes, through which oak pins are thrust for the same purpose.

116. Wooden coverings are little used at the present day, except for temporary purposes: *shingles* of split oak were formerly much used, and may still be seen on the roofs of some country churches.

117. *Metallic Coverings.*—The metals used for roof coverings are lead, zinc, copper, and iron.

118. Lead is one of the most valuable materials for this purpose on account of its malleability and durability, the

action of the atmosphere having no injurious effect upon it. Lead is used for covering roofs in sheets weighing from 4 to 8 lbs. per sup. foot.

119. Copper is used for covering roofs in thin sheets weighing about 16 oz. per sup. foot, and from its lightness and hardness has some advantages over lead; but the expense of the metal effectually precludes its general adoption.

120. Zinc has of late years superseded both lead and copper to a considerable extent as roof coverings. It is used in sheets weighing from 12 oz. to 20 oz. per sup. foot. It is considered an inferior material to those just named; but its lightness and cheapness are great recommendations, and the manufacture has been much improved since its first introduction.

121. Cast iron, coated with zinc to preserve it from rusting, is now much used in a variety of forms. We have already mentioned its adoption for covering the roofs of the new Houses of Parliament. (See Note E, p. 157.)

122. All metallic coverings are subject to contraction and expansion with the changes of the temperature, and great care is requisite in joining the sheets to make them lap over each other, so as to make the joints water-tight, without preventing the play of the metal.

The following table of the comparative weights of different roof coverings may be useful:—

	Cwt.	qrs.	lbs.
Plain tiles, per square of 100 ft. sup.	18	0	0
Pantiles	9	2	0
Slating, an average .	7	0	0
Lead, 7 lb. to the sup. foot . . .	6	2	0
Copper or zinc, 16 oz. do. .	1	0	0

SUPPLY OF WATER.

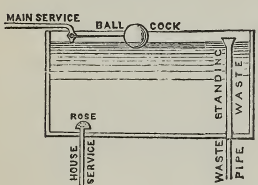
123. The arrangements for distributing a supply of water over the different parts of a building will depend very materially on the nature of the supply, whether constant or intermittent.

The most common method of supply from water-works is by pipes which communicate with private cisterns, into which the water is turned at stated intervals.

A cistern, in a dwelling-house, is always more or less an evil; it takes up a great deal of space, costs a great deal of money in the first instance, and often causes inconvenience, from leakage, from the bursting of the service pipes in frosty weather, and from the liability of the self-acting cock to get out of order

Fig. 74 shows the ordinary arrangements of a cistern for a dwelling-house. The common material for the cistern itself is wood lined with sheet lead; but slate cisterns have been much used of late. Large cisterns or tanks for the supply of breweries, manufactories, &c., are usually made of cast-iron plates, screwed together by means of flanges all round their edges.

Fig. 74.



The service or feed pipe for a cistern, in the case of an intermittent supply, must be sufficiently large to allow of its filling during the time the water is turned on from the mains. The flow of water into the cistern is regulated by a *ball cock*, so called from its being opened and shut by a lever, with a copper ball, which floats on the surface of the water.

The service pipes to the different parts of the building are laid into the bottom of the cistern, but should not come within an inch of the actual bottom, in order that the sediment, which is always deposited in a greater or less degree, may not be disturbed: the mouth of each pipe should be covered by a *rose*, to prevent any foreign substances being washed into the pipes and choking the taps.

To afford a ready means of cleaning out the cistern, a waste pipe is inserted quite at the bottom, sufficiently large to draw off the whole contents in a short time when required; into this waste pipe is fitted a *standing waste*, which

reaches nearly to the top of the cistern, and carries off the waste water, when, from any derangement in the working of the ball cock, the water continues running after the cistern is full To prevent any leakage at the bottom of the standing waste, the latter terminates in a brass plug, which is ground to fit a washer inserted at the top of the waste pipe.

Where the supply of water is *constant*, instead of being intermittent, private cisterns may be altogether dispensed with; the main service pipes, not being required to discharge a large quantity of water in a short time, may be of smaller bore, and, consequently, cheaper, and a considerable length of pipe is saved, as the water can be laid on directly to the several taps, instead of having to be taken up to the cistern and then brought back again. The constant flow of water through the pipes also much diminishes the risk of their bursting in frosty weather from freezing of their contents.

WARMING AND VENTILATION.

124. The various contrivances employed for warming buildings may be classed as under:—

Methods of Warming independently of Ventilation.

1st. By close stoves, the heating surface being either of iron or of earthenware.

2nd. By hot-air flues, passing under the floors.

3rd. By a system of endless piping heated by a current of hot water from a boiler, the circulation being caused by the cooling, and consequently greater weight, of the water in the lower or returning pipe.

Methods of Warming combined with Ventilation.

4th. By open fires placed in the several apartments.

5th. By causing air which has been previously heated to pass through the several rooms. This last system is more perfect than any of the others above described, both as regards economy of fuel and regulation of the temperature.

A great though common defect in the construction of fireplaces is their being placed too high; whence it is not unusual for the upper part of a room to be quite warm whilst there is a stratum of cold air next the floor, the effect of which is very injurious to health.

In all methods of warming, in which the air is heated by coming in contact with metallic heating surfaces, care should be taken that their temperature should not exceed 212°; as, when this limit is exceeded, the air becomes unfit for use, and offensive from the scorching of the particles of dust or other matters that are always floating in it.

125. There are two modes in which artificial ventilation is effected, each of which is very efficient.

The one most in use is to establish a draught in an air shaft or chimney communicating by flues with the apartments to be ventilated, the effect of which is to cause a constant current in the direction of the shaft, the air being admitted at the bottom of the building, and warmed or cooled as may be required, according to the season of the year.

The new House of Lords is ventilated in this manner The air is admitted at the bottom of the buildings, filtered by being passed through fine sieves, over which a stream of water is constantly flowing; warmed in cold weather by passing through steam cockles, and then, rising through the building, goes out through the roof into the furnace chimney, the draught being assisted by a steam jet from a boiler.

126. The other mode of ventilation to which we have alluded is on a completely opposite principle to that just described, the air being *forced into* the apartments by mechanical means, instead of being *drawn from* them by the draught in the chimney.

This latter plan is used with great success at the Reform Club House, the General Post-Office, and many other buildings, the air being thrown in by the action of large fans driven by steam power. (See Note F, p. 157.)

DRAINAGE.

127 This is a subject of equal importance with any of those previously noticed; but as two volumes of this series are devoted to its consideration, it is unnecessary to enter upon it in these pages.

SECTION II.

MATERIALS USED IN BUILDING.

128. The materials used in building may be classed under the following heads, viz.—

TIMBER.

STONE.—*See* volume on "Blasting Rocks and on Stone."

SLATE.—*See* Section IV. Art. 234.

BRICKS AND TILES.—*See* volume on "Brick-making and Tile-making."

LIMES AND CEMENTS.—*See* also Mr. Burnell's volume, in this series.

METALS.

GLASS.—*See* Section IV. Art. 258.

COLOURS AND VARNISHES.—*See* volume on "House-painting and Mixing Colours."

Some of these form the subjects of separate volumes of this series, to which the reader is therefore referred as above; and others are noticed in Section IV. of this volume Our remarks in this section will, therefore, be exclusively confined to the consideration of Timber, Limes and Cements, and Metals.

TIMBER.

129. If we examine a transverse section of the stem of a tree, we perceive it to consist of three distinct parts: the *bark*, the *wood*, and the *pith*. The wood appears disposed in rings round the pith, the outer rings being softer and containing more sap than those immediately round the pith which form what is called the *heart wood.*

These rings are also traversed by rays extending from the centre of the stem to the bark, called *medullary rays.*

The whole structure of a tree consists of minute vessels and cells, the former conveying the sap through the wood in its ascent, and through the bark to the leaves in its descent; and the latter performing the functions of secretion and nutrition during the life of the tree. The solid parts of a tree consist almost entirely of the fibrous parts composing the sides of the vessels and cells.

By numerous experiments it has been ascertained that the sap begins to ascend the spring of the year, through the minute vessels in the wood, and descends through the bark to the leaves, and, after passing through them, is deposited in an altered state between the bark and the last year's wood, forming a new layer of bark and sap wood, the old bark being pushed forward.

As the annual layers increase in number, the sapwood ceases to perform its original functions; the fluid parts are evaporated or absorbed by the new wood, and, the sides of the vessels being pressed together by the growth of the latter, the sapwood becomes heartwood or perfect wood, and until this change takes place it is unfit for the purposes of the builder.

The vessels in each layer of wood are largest on the side nearest the centre of the stem, and smallest at the outside. This arises from the first being formed in the spring, when vegetation is most active. The oblong cells which surround the vessels are filled with fluids in the early growth; but, as the tree increases in size, these become evaporated and absorbed, and the cells become partly filled with depositions of woody matter and indurated secretions, depending on the nature of the soil, and affecting the quality of the timber. Thus Honduras mahogany is full of black specks, while the Spanish is full of minute white particles, giving the wood the appearance of having been rubbed over with chalk. At a meeting of the Institution of Civil Engineers, March, 1842, it was stated by Professor Brande, that "a

beech tree in Sir John Sebright's park in Hertfordshire, on being cut down, was found perfectly black all up the heart. On examination it was discovered that the tree had grown upon a mass of iron scoriæ from an ancient furnace, and that the wood had absorbed the salt of iron." This anecdote well explains the differences that exist between different specimens of the same kind of timber under different circumstances of growth; and it is probably the nature of the soil that causes the difference of character we have just named between Honduras and Spanish mahogany.

There is a great difference in the character of the annual rings in different kinds of trees. In some they are very distinct, the side next the heart being porous, and the other compact and hard, as in the oak, the ash, and the elm. In others the distinction between the rings is so small as scarcely to be distinguished, and the texture of the wood is nearly uniform, as in the beech and mahogany. A third class of trees have the annual rings very distinct and their pores filled with resinous matter, one part being hard and heavy, the other soft and light-coloured. All the resinous woods have this character, as larch, fir, pine, and cedar.

The medullary rings are scarcely perceptible to the naked eye in the majority of trees; but in some, as the oak and the beech, there are both large and small rings, which, when cut through obliquely, produce the beautiful flowered appearance called the silver grain.

130. In preparing timber for the uses of the builder there are three principal things to be attended to, viz. the age of the tree, the time of felling, and the seasoning for use.

131. If a tree be felled before it is of full age, whilst the heartwood is scarcely perfected, the timber will be of inferior quality, and, from the quantity of sap contained in it, will be very liable to decay. On the other hand, if the tree be allowed to stand until the heartwood begins to decay, the timber will be weak and brittle: the best timber

comes from trees that have nearly done growing, as there is then but little sapwood, and the heartwood is in the best condition.

132. The best time for felling trees is either in mid-winter, when the sap has ceased to flow, or in midsummer, when the sap is temporarily expended in the production of leaves. An excellent plan is to bark the timber in the spring and fell it in winter, by which means the sapwood is dried up and hardened; but as the bark of most trees is valueless, the oak tree (whose bark is used in tanning) is almost the only one that will pay for being thus treated.

133. The seasoning of timber consists in the extraction or evaporation of the fluid parts, which are liable to decomposition on the cessation of the growth of the tree. This is usually effected by steeping the green timber in water, to dilute and wash out the sap as much as possible, and then drying it thoroughly by exposure to the air in an airy situation. The time required to season timber thoroughly in this manner will of course much depend on the sizes of the pieces to be seasoned; but for general purposes of carpentry, two years is the least that can be allowed, and, in seasoning timber for the use of the joiner, a much longer time is usually required.

134. *Decay of Timber.*—Properly seasoned timber, placed in a dry situation with a free circulation of air round it, is very durable, and has been known to last for several hundred years without apparent deterioration. This is not, however, the case when exposed to moisture, which is always more or less prejudicial to its durability.

When timber is constantly under water, the action of the water dissolves a portion of its substance, which is made apparent by its becoming covered with a coat of slime. If it be exposed to alternations of dryness and moisture, as in the case of piles in tidal waters, the dissolved parts being continually removed by evaporation and the action of the water, new surfaces are exposed, and the wood rapidly decays.

Where timber is exposed to heat and moisture, the albumen or gelatinous matter in the sapwood speedily putrefies and decomposes, causing what is called rot. The rot in timber is commonly divided into two kinds, the *wet* and the *dry*, but the chief difference between them is, that where the timber is exposed to the air, the gaseous products are freely evaporated; whilst, in a confined situation, they combine in a new form, viz. the dry-rot fungus, which, deriving its nourishment from the decaying timber, often grows to a length of many feet, spreading in every direction, and insinuating its delicate fibres even through the joints of brick walls.

In addition to the sources of decay above mentioned, timber placed in sea water is very liable to be completely destroyed by the perforations of the worm, unless protected by copper sheathing, the expense of which causes it to be seldom used for this purpose.

135. *Prevention of Decay.*—The best method of protecting woodwork from decay when exposed to the weather is to paint it thoroughly, so as to prevent its being affected by moisture. It is, however, most important not to apply paint to any woodwork which has not been thoroughly seasoned; for in this case the evaporation of the sap being prevented, it decomposes, and the wood rapidly decays.

Many plans have been proposed for the prevention of the rot. Kyan's process * consists in impregnating the timber with corrosive sublimate, thus converting the albumen into an indecomposable substance. This method, although not always successful, is undoubtedly of great use, particularly where inferior or imperfectly seasoned timber has to be used. It is, however, said to render the wood brittle.

Payne's process † consists in impregnating the wood with metallic oxides, alkalies, or earths, as may be required, and decomposing them in the wood, forming new and insoluble compounds. Timber thus prepared will not burn, but only smoulder

* Patented A.D. 1832. † Patented A.D. 1841.

A process invented by Mr. Bethell,* and much used in railway works, is to impregnate the timber with oil of tar: this appears to be very successful in preventing decay, but the danger of accidents from fire is much increased. †

136. The variety of timber trees suitable to the purposes of the builder is very great; but fir and oak are the kinds chiefly used, although larch, beech, poplar and other woods, are employed to a limited extent in localities where they can be obtained more cheaply than foreign timber. Very little home-grown fir is used in England, as foreign timber, either in balks, or cut up into planks, deals, or battens, can be obtained at a moderate price in all the large towns in the kingdom, and is very superior to any grown in this country. Baltic timber is more esteemed than American, but a very great deal of the latter is used.

137. Fir is one of the most useful of the woods used by the builder. It is light, soft, easily worked, and very durable; but the lateral cohesion of the annual rings being very slight, it will not bear much strain, except in the direction of the length of the fibres. Red pine is also much used for carpenters' work, and is very durable. Yellow pine is sometimes used for joiners' work, but it is an inferior material, and liable to rot.

138. Oak, for purposes requiring strength, is preferred of English growth; that from Sussex is considered the best, being hard and fine-grained. The Dutch wainscot, which is grown in Germany, is a softer kind, and on that account not so apt to warp and twist, for which reason it is preferred to English oak for the purposes of the joiner: the texture of oak is very uniform, hard, and compact, which renders it superior to all other woods, as it will bear to be strained in any direction without fear of the rings separating, as in the resinous woods.

139. For internal finishings, mahogany is much used; that called Spanish, which comes from the West India Islands, is considered the best.

* Patented in 1838. † See Note G, p. 158.

For joiners' and cabinet-makers' work, a great many kinds of fancy wood are imported, which are cut by machinery into thin slices, called *veneers*, and used as an ornamental covering to inferior work. In veneering, care should be taken that the body of the work be thoroughly seasoned, or it will shrink, and the veneer will fly off.

LIMES AND CEMENTS, MORTAR, ETC.

140. So much of the stability of brickwork and masonry depends upon the binding properties of the mortar or cement with which the materials are united, especially when exposed to a side pressure, as in the case of retaining walls, arches, and piers, that it is of no small importance to ascertain on what the strength of mortar really depends, and how far the proportions of the ingredients require modification, according to the quality of the lime that may have to be used.

It was long supposed that the hardness of any mortar depended upon the hardness of the limestone, from which the lime used in its composition was derived; but it was ascertained by the celebrated Smeaton, and since his time clearly shown by the researches of others, amongst whom may be named, Vicat in France, and Lieutenant-General Sir Charles Pasley in this country, that the hardness of the limestone has nothing to do with the matter, and that it is its chemical composition which regulates the quality of the mortar.

141. Limestone may be divided into three classes.

1st. Pure limes—as chalk.

2nd. Water limes—some of which are only slightly hydraulic, as the stone limes of the lower chalk, whilst others are eminently so, as the lias limes.

3rd. Water cements—as those of Sheppy and Harwich.

142. In making mortar the following processes are gone through.

1st. The limestone is calcined by exposure to strong

heat in a kiln, which drives off the carbonic acid gas contained in it, and reduces it to the state of *quick-lime.*

2nd. The quick-lime is *slaked* by pouring water upon it, when it swells, more or less, with considerable heat, and falls into a fine powder, forming a *hydrate* of lime.

3rd. The hydrate thus formed is mixed up into a stiffish paste, with the addition of more water, and a proper proportion of sand, and is then ready for use.

143. *Pure Limes.—Chalk* is a pure carbonate of lime, consisting of about 5 parts of lime combined with 4 of carbonic acid gas. It expands greatly in slaking, and will bear from 3 to $3\frac{1}{2}$ parts of sand to one of lime, when made up into mortar. Chalk lime mortar is, however, of little value, as it *sets* or hardens very slowly, and in moist situations never sets at all, but remains in a pulpy state, which renders it quite unfit for any work subjected to the action of water, or even for the external walls of a building.

144. Gypsum, from which is made *plaster of Paris* for cornices and internal decorations, is granular sulphate of lime, and contains 26·5 of lime, 37·5 of sulphuric acid, and 17 of water. It slakes without swelling, with a moderate heat, setting hard in a very short time, and will even set under water; but as it is, like other pure limes, partly soluble in water, it is not suitable for anything but internal work.

145. *Water limes* have obtained their name from the property they possess in a greater or less degree of setting under water. They are composed of carbonate of lime, mixed with silica, alumina, oxide of iron, and sometimes other substances.

146. *Dorking lime*, obtained from the beds of the lower chalk, at Dorking, in Surrey; and *Halling lime*, from a similar situation near Rochester, in Kent, are the principal limes used in London for making mortar, and are slightly hydraulic; they expand considerably in slaking, but not so much as the pure limes, and will make excellent mortar when mixed with 3 parts of sand to 1 of lime. Mortar

made with these limes sets hard and moderately quick, and *when set*, may be exposed to considerable moisture without injury; but they will not set under water, and are therefore unfit for hydraulic works, unless combined with some other substance, as *puzzolana*, to give them water-setting properties.

147. The *blue lias limes* are the strongest water limes in this country. They slake very slowly, swelling but little in the process, and set very rapidly even under water; a few days only sufficing to make the mortar extremely hard. The lias limes will take a much smaller proportion of sand than the pure limes, the reason of which will be understood when it is remembered that they contain a considerable proportion of silica and alumina, combined with the lime in their natural state, and consequently the proportion of sand which makes good mortar with chalk lime, would ruin mortar made with Aberthaw, Watchet, Barrow, and other lias limes.

In the Vale of Belvoir, where the lias lime is extensively used, the common practice is to use equal parts of lime and sand for inside, and half sand to one of lime for face, work.

148. *Water Cements.*—These differ from the water-limes, as regards their chemical composition, only in containing less of carbonate of lime and more of silica and alumina. They require to be reduced to a fine powder after calcination, without which preparation they cannot be made to slake. The process of slaking is not accompanied by any increase of bulk, and they set under water in a short time, a few hours sufficing for a cement joint to become perfectly hard.

The principal supplies of cement-stone for the London market are derived from Harwich in Essex, and the Isle of Sheppy in Kent; where they are found in the London clay in the form of calcareous nodules.

Cement will not bear much sand without its cementitious properties being greatly weakened, the usual proportion being equal parts of sand and cement

149. The use of natural cement was introduced by Mr Parker, who first discovered the properties of the cement-stone in the Isle of Sheppy, and took out a patent for the sale of it in 1796, under the name of Roman cement.

Before that time, hydraulic mortar, for dock walls, harbour work, &c., was usually made, by mixing common lime with trass, from Andernach in Germany, or with puzzolana from Italy; both are considered to be volcanic products, the latter containing silica and alumina, with a small quantity of lime, potash, and magnesia. Iron is also associated with it in a magnetic state.

150. The expense of natural puzzolana led to the manufacture of artificial puzzolana, which appears to have been used at an early date by the Romans, and has continued in use in the South of Europe to the present day; artificial puzzolana is made of pounded bricks or tile dust. The Dutch manufacture an artificial puzzolana from burnt clay, in imitation of the trass of Andernach, which is said to be a close imitation of the natural product.

151. The great and increasing demand for cement, and its great superiority for most purposes over lime mortar, have induced manufacturers to turn their attention to the manufacture of artificial cement, and this has been attended in many instances with perfect success; the artificial cements now offered for sale, formed by imitating the composition of the natural cement-stones, being mostly equal in quality, if not superior, to the Roman cement, the use of which has been partly superseded by them.

152. The quality of the *sand* used in making mortar is by no means unimportant. It should be clean and sharp; *i. e.* angular, and perfectly free from all impurities. The purer the lime the finer should be the quality of the sand, the pure limes requiring finer, and the cements a coarser sand, than the hydraulic limes.

CONCRETE AND BETON.

153. Rubble masonry, formed of small stones bedded in

mortar, appears to have been commonly used in England from an early period; and similar work, cemented with hydraulic mortar, was constantly made use of by the Romans in their sea-works, of which many remains exist at the present day in a perfectly sound state.

154. This mode of forming foundations, in situations where solid masonry would be inapplicable, has been revived in modern times; in England under the name of concrete, and on the Continent under the name of béton. Although very similar in their nature and use, there are yet great differences between béton and concrete, which depend on the nature of the lime used, concrete being made with the weak water limes which will not set under water, whilst béton is invariably made with water-setting limes, or with limes rendered hydraulic by the addition of puzzolana. Describing the two by their differences, it may be observed that concrete is made with unslaked lime, and immediately thrown into the foundation pit; béton is allowed to stand before use, until the lime is thoroughly slaked: concrete is thrown into its place and rammed to consolidate it; béton is gently lowered and not afterwards disturbed: concrete must be thrown into a dry place, and not exposed to the action of water until thoroughly set; béton, on the contrary, is made use of principally *under water*, to save the trouble and expense of laying dry the bottom.

155. Concrete is usually made with gravel, sand, and ground unslaked lime, mixed together with water, the proportions of sand and lime being those which would make good mortar without the gravel, and, of course, varying according to the quality of the lime; with the common limes, slaking takes place at the time of mixing, and the quality of the concrete is all the better for the freshness of the lime. If lias lime be used, the concrete becomes béton, and must be treated accordingly.

The lime in this case must be thoroughly slaked (which often takes many hours) before it can be considered fit for use; and, if this precaution be not attended to, the whole

of the work, after having set very hard on the surface, cracks and becomes a friable mass, from the slaking of the refractory particles after the body of the concrete has set.

The reader is referred, for further information on this subject, to the volume of this series on "Foundations and Concrete Works."

156. Asphalte, so much in use at the present day for foot-pavements, terrace-roofs, &c., is made by melting the asphalte rock, which is a carbonate of lime intimately combined with bitumen, and adding to it a small portion of mineral tar, which forms a compact semi-elastic solid, admirably adapted for resisting the effects of frost, heat, and wet.

Many artificial asphaltes have been brought under public notice from time to time, but they are all inferior to the natural asphalte, in the intimate combination of the lime and bitumen, which it appears impossible to effect thoroughly by artificial means.

METALS.

157. The metals used as building materials are iron, lead, copper, zinc, and tin.

158. *Iron.*—Iron is used by the builder in two different states, viz. cast iron and wrought iron, the differences between them depending on the proportion of carbon combined with the metal; cast iron containing the most, and wrought iron the least.

159. Previous to the middle of the last century, the smelting of iron was carried on with wood charcoal, and the ores used were chiefly from the secondary strata, although the clay ironstones of the coal measures were occasionally used.

The weald of Kent and Sussex* contained many ironworks during the seventeenth century. That at Lamberhurst, near Tunbridge Wells in Sussex, is noted as having

* The clay ironstones of Sussex are very rich, and are still raised in considerable quantities, and shipped for Wales and Newcastle.

furnished the cast-iron railing round St. Paul's Cathedral. The tilt hammers used in forging bar iron were chiefly worked by water power. A large pool in Beeding Forest, near Horsham in Sussex, still retains the name of the Hammer Pond, and the former sites of many old forges in the wealden district may still be traced by the heaps of cinders which yet remain here and there, and by the local names to which the works gave rise.

160. The introduction of smelting with pitcoal coke during the last century caused a complete revolution in the iron trade. The ores now chiefly used are the clay ironstones of the coal measures, and the fuel, pitcoal or coke. Steam power is almost exclusively used for the production of the blast in the furnaces, and for working the forge hammers and rolling mills.

161. For the production of wrought iron in the ordinary manner, two distinct sets of processes are required. 1st. The extraction of the metal from the ore in the shape of cast iron. 2nd. The conversion of cast iron into malleable or bar-iron, by re-melting, puddling, and forging. The conversion of bar iron into steel is effected by placing it in contact with powdered charcoal in a furnace of cementation. (See Note H, p. 158.)

162. *Cast iron* is produced by smelting the previously calcined ore in a blast furnace, with a portion of limestone as a flux, and pitcoal or coke as fuel. The melted metal sinks to the bottom of the furnace by its greater specific gravity. The limestone and other impurities float on the top of the melted mass, and are allowed to run off, forming *slag* or *cinder*. The melted metal is run off from the bottom of the furnace into moulds, where castings are required, and into furrows made in a level bed of sand, when the metal is required for conversion into malleable iron, the bars thus produced being called *pigs*.

163. In the year 1827, it was discovered that by the use of heated air for the blast, a great saving of fuel could be effected, as compared with the cold blast process.

The hot blast is now very extensively in use, and has the double advantage of requiring less fuel to bring down an equal quantity of metal, and of enabling the manufacturer to use raw pitcoal instead of coke, so that a saving is effected both in the quantity and cost of the fuel.

For a considerable time after its introduction it was held in great disrepute, which, however, may be chiefly attributed to the inferior quality of materials used, the power of the hot blast in reducing the most refractory ores offering a great temptation to obtain a much larger product from the furnace than was compatible with the good quality of the metal. The use of the hot blast by firms of acknowledged character has greatly tended to remove the prejudice against it; and in many iron works of high character, nothing but the hot blast with pitcoal is used in the smelting furnaces, the use of coke being confined to the subsequent processes.

Perhaps it may be laid down as a general principle, that where the pig iron is re-melted with coke in the cupola furnace, for the purposes of the ironfounder; or refined with coke in the conversion of forge pig into bar iron, it is of little consequence whether the reduction of the ore has been effected with the hot or the cold blast; but where castings have to be run directly from the smelting furnace, the quality of the metal will, no doubt, suffer from the use of the former.

164. Cast iron is divided by ironfounders into three qualities. No. 1, or *black cast iron*, is coarse-grained, soft, and not very tenacious. When re-melted it passes into No. 2, or *grey cast iron*. This is the best quality for castings requiring strength: it is more finely grained than No. 1, and is harder and more tenacious. When repeatedly re-melted it becomes excessively hard and brittle, and passes into No. 3, or *white cast iron*, which is only used for the commonest castings, as sash-weights, cannon-balls, and similar articles. White cast iron, if produced direct from the ore, is an indication of derangement in the working of the furnace, and

is unfit for the ordinary purposes of the founder, except to mix with other qualities. (See Note I, p. 159.)

165. Girders and similar solid articles are cast in sand moulds, enclosed in iron frames or *boxes*, each mould requiring an upper and lower box. A mould is formed by pressing sand firmly round a wooden *pattern*, which is afterwards removed, and the melted metal poured into the space thus left through apertures made for the purpose.

The moulds for ornamental work and for hollow castings are of a more complicated construction, which will be better understood from actual inspection at a foundry than from any written description.

Almost all irons are improved by admixture with others, and, therefore, where superior castings are required they should not be run direct from the smelting furnace, but the metal should be re-melted in a cupola furnace, which gives the opportunity of suiting the quality of the iron to its intended use. Thus, for delicate ornamental work, a soft and very fluid iron will be required, whilst, for girders and castings exposed to cross strain, the metal will require to be harder and more tenacious. For bed-plates and castings which have merely to sustain a compressing force, the chief point to be attended to is the hardness of the metal.

Castings should be allowed to remain in the sand until cool, as the quality of the metal is greatly injured by the rapid and irregular cooling which takes place from exposure to air if removed from the moulds in a red-hot state, which is sometimes done in small foundries to economise room

Staffordshire, Shropshire, and Derbyshire, afford the best irons for castings. The Scotch iron is much esteemed for hollow wares, and has a beautifully smooth surface, which may be noticed in the stoves and other articles cast by the Carron Company.

The Welsh iron is principally used for conversion into bar iron.

166. The conversion of forge pig into bar iron is effected by a variety of processes, which have for their object the

freeing the metal from the carbon and other impurities combined with it, so as to produce as nearly as possible the pure metal. We do not purpose to enter in these pages into any of the details of the manufacture of bar iron, or of its conversion into steel, as our business is rather with the ironfounder than the manufacturer; it may, however, be proper to state, that new processes have lately been patented, by which both malleable iron and steel may be produced directly from the ore, without the use of the smelting furnace, a plan which is likely to be attended with beneficial results, both as regards economy and quality of metal.

167. *Lead.*—Lead is used by the mason for securing dowels, coating iron cramps, and similar purposes, *see* Section IV., Plumber.

Lead is also used by the smith in fixing iron railings, and other work where iron is let into stone; but the use of lead in contact with iron is always to be avoided, if possible, as it has an injurious effect upon the latter metal, the part in contact with the lead becoming gradually softened.

The chief value of lead, however, to the builder, is as a covering for roofs, and for lining gutters, cisterns, &c., for which uses it is superior to any other metal. For these purposes the lead is cast into sheets, and then passed between rollers in a *flatting-mill*, until it has been reduced to the required thickness.

Cast-lead is often made by plumbers themselves from old lead taken in exchange; but it is very inferior to the *milled lead* of the manufacturer, being not so compact, and often containing small air-holes, which render it unfit for any but inferior purposes.

168. *Copper.*—*See* Section IV., Coppersmith.

169. *Zinc.*—*See* Section IV., Zincworker.

170. *Brass* is an alloy of copper and zinc, the best proportions being nearly two parts of copper to one of zinc.

171. *Bronze* is a compound metal, composed of copper and tin, to which are sometimes added a little zinc and lead.

The best proportions for casting statues and bas-reliefs appear to be attained when the tin forms about 10 per cent. of the alloy.

By alloying copper with tin, a more fusible metal is obtained, and the alloy is much harder than pure copper; but considerable management is required to prevent the copper from becoming refined in the process of melting, a result which has frequently happened to inexperienced founders.

172. *Bell-metal* is composed of copper and tin, in the proportion of 78 per cent. of the former to 22 per cent. of the latter.

SECTION III.

STRENGTH OF MATERIALS.

173. There are three principal actions to which the materials of a building are exposed.

1st. *Compression*—as in the case of the stones in a wall.

2nd *Tension*—as in the case of a king-post or tie-beam.

3rd. *Cross strain*—as in the case of a bressummer, floor-joists, &c.

The last of the three is the only one against which precautions are especially necessary, as in all ordinary cases the resistance of the materials used for building is far beyond any direct crushing or pulling force that is likely to be brought upon them.

174. 1st. *Resistance to Compression.*—The following table shows the force required to crush $1\frac{1}{2}$ in. cubes of several kinds of building material.—

	lbs.		lbs.
Good brick . . .	1817	Portland stone .	10,284
Derbyshire grit .	7070	Granite ,, .	14,300

These amounts so far exceed any weight that could have to be borne on an equal area, under ordinary circumstances, that it is quite unnecessary in the erection of a building to make any calculations on this head when using these or similar materials.

Cast iron may be considered as practicably incompressible; *wrought iron* may be flattened under great pressure, but cannot be crushed. *Timber* may be considered, for practical purposes, as nearly incompressible, when the weight is applied in the direction of the fibres, as in the case of a wooden story-post; but the softer kinds, as fir, offer little resistance, when the weight is applied at right angles to the fibres, as in the case of the sill of a partition; and, besides this, timber, however well-seasoned, will always shrink, more or less, in the direction of its thickness, so that no important bearings should be trusted to it.

175. 2nd. *Resistance to Tension.*—The principal building materials that are required to resist direct tension are *timber* and *wrought iron.* (See Note K, p. 159.)

The following table shows the weight in tons required to tear asunder bars 1-inch square of the following materials:—

	Tons.
Oak	$5\frac{1}{5}$
Fir	$5\frac{1}{4}$
Cast iron	$7\frac{3}{4}$
Wrought iron	10
Wrought copper	15
English bar iron	25
Blistered steel	$59\frac{1}{2}$

Cast iron, however, although included in the above table, is an unsuitable material for the purpose of resisting tension, being comparatively brittle. With regard to *timber*, it is practicably impossible to tear asunder a piece of even

moderate size, by a force applied in the direction of the fibres, and therefore the dimensions of king-posts, tie-beams, and other timbers which have to resist a pulling force, are regulated by the necessity of forming proper joints and connections with the other parts of the framing to which they belong, rather than by their cohesive strength. But it must be borne in mind, that although the strength of all kinds of timber is very great in the direction of the fibres, the lateral cohesion of the annual rings is in many kinds of wood very slight, and must be assisted by iron straps in all doubtful cases. The architects of the middle ages executed their magnificent wooden roofs without these aids, but they worked in oak, and not in soft fir, which would split and rend if treated in the same way.

Wrought iron is extensively used for bolts, straps, tie-rods, and all purposes which require great strength, with small sectional area; one-fourth of the breaking weight is usually said to be the limit to which it should be strained; but, in all probability, this amount might be doubled without any injurious effects.

STRENGTH OF BEAMS.

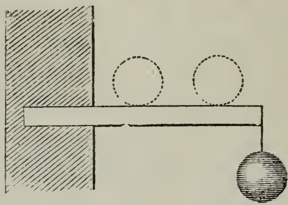
176. 3rd. *Cross Strain.*—In calculating the strength of beams when exposed to cross or transverse strain, two principal considerations present themselves: 1st, The mechanical effect which any given load will produce under varying conditions of support; and 2ndly, The resistance of the beam, and the manner in which this is affected by the form of its section.

177. 1st. *Mechanical Effect of a given Load under varying Circumstances.*—If a rectangular beam be supported at each end and loaded in the middle, the strength of the beam, its section remaining the same, will be inversely as the distance between the supports, the weight acting with a leverage which increases at this distance.* If a beam be

* It may be as well to observe that, although this is true as to the strength of beams under ordinary circumstances, it does not hold good when

fixed at one end and weighted at the other (fig. 75), its strength will be half that of a similar beam of double the

Fig. 75.



length supported as first described (fig 76). A parallel case to this is that of a beam supported in the middle and

Fig. 76.

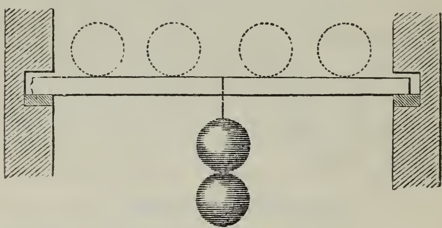
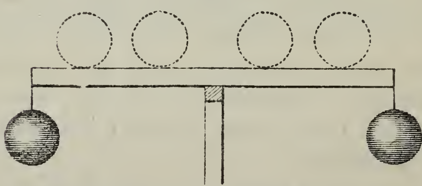


Fig. 77.

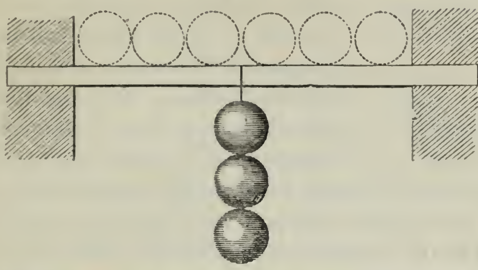


loaded at the ends (fig 77). In each of the above cases the beam will bear double the load if it be equally distributed over its whole length, as shown by the dotted lines;

the loading is carried to the breaking point, the deflection of the beam causing an increase or diminution of the leverage according to the mode of support. The difference of strength arising from this cause is, however, too trifling to be taken into consideration, except in delicate experiments on the ultimate strength of beams.

and lastly, the strength of a beam firmly fixed at the ends is to its strength when loosely laid on supports as 3 to 2 (*see* fig. 78).

Fig. 78.



These results may be simply expressed thus:

Let *s* be the weight which would break a beam of given length and scantling fixed at one end and loaded at the other;

then 2 *s* would break the same beam fixed at one end and uniformly loaded;

4 *s* would break the same beam supported at each end and loaded in the middle;

6 *s* would break the same beam fixed at each end and loaded in the middle;

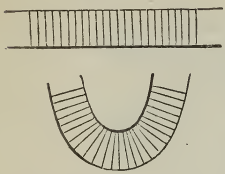
8 *s* would break the same beam supported at each end and uniformly loaded;

12 *s* would break the same beam fixed at each end and uniformly loaded.

178. 2nd. *Resistance of the Beam.*—If a beam be loaded so as to produce fracture, this will take place about a centre or neutral axis, below which the fibres will be *torn* asunder, and above which they will be crushed. This may be very clearly illustrated by drawing a number of parallel lines with a soft pencil on the edge of a piece of India rubber, and bending it round, when it will be seen that the lines are brought closer together on the concave, and stretched further asunder on the convex side, whilst, between the two edges, a neutral line may be traced, on which the divisions

remain of the original size, which neutral line divides the fibres that are subjected to compression from those in a state of tension (*see* fig. 79).

Fig. 79.



The resistance of a rectangular beam will, therefore, depend, 1st, on the number of fibres, which will be proportionate to its breadth and depth; 2nd, on the distance of those fibres from the neutral axis, and the consequent leverage with which they act, which will also be as the depth; and, lastly, on the actual strength of the fibres, which will vary with different materials, and can only be determined approximately from actual experiments on rectangular beams of the same material as those whose strength is required to be estimated.

The actual strength of any rectangular beam will, therefore, be directly as its breadth multiplied by the square of the depth, and inversely as its length; or, calling s the transverse strength of the material, as in art. 177, b the breadth, d the depth, l the length between the supports, and W the breaking weight,

$$W = \frac{s\,b\,d^2}{l}$$

The following may be taken as the value of s for iron and timber, the length being taken in feet, the breadth and depth in inches, and the breaking weight in pounds.

	Constant multiplier or rectangular beams fixed at one end and loaded at the other.		Constant multiplier for rectangular beams loosely supported at the ends and loaded in the middle.
Wrought iron	512	× 4	2048
Cast ditto	500		2000*
Fir and English oak	100		400

* The above is an average value calculated from a great number of published experiments on different irons. The best Derbyshire and Staffordshire irons might probably be taken as high as 2500, whilst the ordinary Scotch hot-blast irons could not be trusted to bear more than from 1700 to 1900.

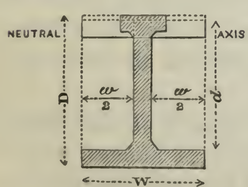
It must be remembered that the numbers here given indicate the breaking weight, not more than one-third of which should ever be applied in practice. Timber is permanently injured if more than even one-fourth of the breaking weight is placed on it, and, therefore, this limit should never be passed.

A single example will suffice to show the importance of the principles just explained, and the lamentable results that may follow from ignorance of them. If we take a fir binding joist, say 9 in. × 4 in., which is to have a bearing of 12 ft. between its supports, and place it edgeways, it will require to break it a weight $= \dfrac{400 \times 4 \times 9^2}{12} = 10{,}800$ lbs.: but if, for the purpose of gaining height, we place it flatways, it will break with a weight $= \dfrac{400 \times 9 \times 4^2}{12} = 4800$ lbs., or less than one-half.

179. We may see from this example that the shape of any beam has a great influence on its strength; and in making beams of iron, which can be cast with great facility in any required shape, it becomes an important question how to obtain the strongest form of section with the least expenditure of metal.

The usual section given to cast-iron girders is that of a thin and deep rectangular beam, with flanges or projections on each side at top and bottom; where the strength of the metal will be most effective, as being at the greatest possible distance from the neutral axis (fig. 80).

Fig. 80.



The great question now is, what should be the relative thickness of the top and bottom flanges, the centre part of the beam having been made as thin as is consistent with sound casting?

If the metal were incompressible, the top flanges might be infinitely thin; if incapable of extension, the bottom

ones might be indefinitely reduced. If it offered equal resistance to tension and compression, the neutral axis would occupy the centre of the beam, and the top and bottom flanges would require to be of equal strength.

We are indebted to Mr. Eaton Hodgkinson for the publication * of a valuable set of experiments conducted by him, having for their object the determination of the position of the neutral axis in cast-iron beams. The result of his experiments is, that in cast-iron rectangular beams, the position of the neutral axis at the time of fracture is at about one-seventh of the whole depth of the beam below its upper surface Hence, in girders with flanges, the thickness of the bottom flanges should be six times that of the upper ones (supposing them to be of the same width), in order to obtain the greatest strength with the least metal. Practically it would be almost impossible to cast a beam thus proportioned, and, therefore, the top flanges are made of the same thickness, or nearly so, as the bottom ones, but of a less width, so as to contain the same relative quantity of metal, disposed in a more convenient form for casting (fig. 80).

The difficulty of making sound castings where the parts are of unequal thickness also renders it necessary to make the thickness of the middle rib nearly equal to that of the flanges.

180. To calculate the strength of a cast-iron beam, the sectional area of whose top flanges is $\frac{1}{6}$ of that of the bottom ones, we must find that of a rectangular beam of the same extreme depth and width, and deduct from it the resistance of the portions omitted between the top and bottom flanges (fig. 80).

If we call the whole width of the bottom of the beam, W, the sum of the widths of the two bottom flanges, w, the whole depth of the beam, D, and the vertical distance between the flanges d (on the supposition that the top flanges

* Experimental Researches on the Strength and other Properties of Cast Iron, 8vo, 1846. WEALE.

are of the same widths as the bottom ones, and $\frac{1}{6}$ of their thickness, as shown by the dotted lines in fig. 80), the distance between the supports, l, the strength of the material, s, as in art. 177, and if the weight required to break a beam when loosely supported at the ends and loaded in the middle be called x,

$$\text{Then } x = \frac{(\text{W D}^2 - w\,d^2)\,4\,s}{l},$$

and if we take the length in feet and the other dimensions in inches, and call $s = 560$ lbs., which is not too much for the best Staffordshire irons; then

$$4\,s = 2240 \text{ lbs.} = 1 \text{ ton; and therefore } \frac{\text{W D}^2 - w\,d^2}{l} =$$

breaking weight in tons.

The value of d in this rule will be D $-$ $\frac{1}{6}$ of the thickness of the bottom flanges, and so long as the sectional area of the top flanges is more than $\frac{1}{6}$ of that of the bottom ones,* the rule may be applied to girders of variously proportioned flanges, as the additional strength gained by increasing the size of the top flanges beyond the proportion here named is very small in proportion to the metal used, and, in neglecting to take it into account, we are sure to err on the safe side.

181. It must not be supposed, that because increasing the thickness of the top flanges does not materially increase the resistance to vertical pressure, it is on that account useless: on the contrary, where a beam is of considerable depth in proportion to the widths of the bottom flanges, it will often be desirable to make the top flanges more than $\frac{1}{6}$ of the bottom ones, in order to prevent the girder from twisting laterally, and to increase the resistance to any side

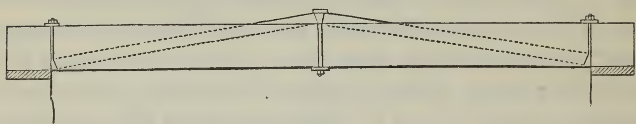
* It must be remembered that in making the top flanges narrower than the bottom ones for convenience of casting, as the bulk of the metal is brought nearer to the neutral axis by so doing, the sectional area of the top flanges must be rather more than $\frac{1}{6}$ of that of the bottom ones, in order to keep the position of the neutral axis the same as in a rectangular beam.

thrust to which it may be exposed from brick arches or otherwise.

182. In practice, it is not desirable to load iron girders beyond $\frac{1}{3}$ of their ultimate strength, and they should be *proved* before use by loading them to this extent or a little more, but care should be taken never to let the proof exceed $\frac{1}{2}$ the breaking weight, as a greater load than this strains and distresses the metal, making it permanently weaker. The ultimate strength of a girder of the usual proportions may be approximately ascertained from its deflexion under proof on the assumption that a load equal to half the breaking weight will cause a deflection of $\frac{1}{480}$ of its length.*

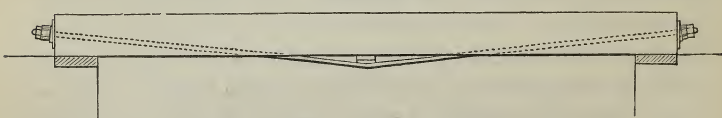
183. *Trussed Timber Beams.*—Timbers exposed to severe strain require to be *trussed* with iron, and this may be done in two ways: 1st, by inserting cast-iron struts, as in fig. 81,

Fig. 81.



thus placing the whole, or nearly the whole, of the woodwork in a state of tension; 2nd, by wrought-iron tension, rods, as in fig. 82, which take the whole of the tension,

Fig. 82.



whilst the timber is thrown entirely into compression The latter mode of trussing is now very extensively used in strengthening the carriages of travelling cranes and for similar purposes; and, by its use, a balk of timber which will barely support its own weight safely without assistance,

* The author is indebted for this rule to the manager of the Phœnix Foundry, Derby. See also Note L. p. 160.

may be made to carry a load of many tons without sensible deflection.

STRENGTH OF STORY-POSTS AND CAST-IRON PILLARS.

184. When a piece of timber, whose length is not less than 8 or 10 times its diameter, is compressed in the direction of its length, as in the case of a wooden story-post supporting a bressummer, it will give way if loaded beyond a certain point, not by crushing, but by bending, and will ultimately be destroyed by the cross strain, just as a horizontal beam would be by vertical pressure applied at right angles to the fibres. The rules for determining the dimensions of a piece of timber to support a given weight without sensible flexure are very complicated, and are of little practical value, as they depend upon the condition that the pressure is exactly in the direction of the axis of the post—a condition rarely fulfilled in practice.

185. Wooden story-posts have been to a great extent superseded by the use of cast-iron pillars, which possess great strength with a small sectional area, and are on that account particularly well adapted to situations where it is of consequence to avoid obstructing light, as in shop-fronts.

In determining the design of a cast-iron pillar, whose length is 20 or 30 times its diameter, two points have to be considered: 1st, the liability to flexure; 2nd, the risk of the ends being crushed by the load not acting in the direction of the axis of the pillar.

Fig. 83.

The resistance to flexure is greatly increased by enlarging the bearing surface at the ends of the pillar, as in fig. 83, which, on the other hand, increases the liability of the ends to fracture, in the event of the load being thrown on the side instead of on the centre of the column, by any irregular settlement of the building. The judicious architect will, therefore, take a mean course, swelling out the capitals and bases of his cast-iron pillars enough to prevent their shafts from bend-

ing, but at the same time avoiding any thin flanges or projections, which might be liable to be broken. No theoretical rule for determining the proportions of a cast-iron pillar depending on the weight to be supported can be depended on in practice. The real measure of the strength of a cast-iron story-post must be the power of resisting any lateral force which may be brought against it; and as a slight side blow will suffice to fracture a pillar which is capable of supporting a vertical pressure of very many tons, we have only to make sure of the lateral strength, and we are quite certain to be on the safe side as regards any vertical pressure which it may have to sustain.

186. Besides the above cases of transverse strain, there are others arising from irregular settlements, which are amongst the greatest difficulties with which the builder has to contend. Thus, to take a familiar instance, the window sills of a dwelling-house are often broken by the settlement of the brickwork being greater in the piers than under the sills, from the greater pressure on the mortar joints; and this will take place with a difference of settlement which can scarcely be detected, even by careful measurement.* We need not here enlarge on this subject, as we have several times in the preceding pages had occasion to notice both the causes of irregular settlement, and the precautions to be taken for its prevention

The strength of materials to resist *torsion* or twisting, as in the case of a driving shaft, is an important consideration in the construction of machinery, but is of little consequence in the erection of buildings, and therefore need not be noticed in these pages

* The reader need scarcely be told that a careful builder will always defer *pinning up* his sills until some time has been allowed for the settlement of the brickwork, but this will not always prevent ultimate fracture.

SECTION IV.

USE OF MATERIALS.

EXCAVATOR.

187. The digging required for the foundations of common buildings usually forms part of the business of the bricklayer, and is paid for at per cubic yard, according to the depth of the excavation, and the distance to which the earth has to be wheeled; this being estimated by the *run* of 20 yards.

In large works, which require coffer-dams and pumping apparatus to be put down before the ground can be got out for the foundations, the work assumes a different character, and is paid for accordingly; the actual excavation being only a small item of the total cost compared with those of dredging, piling, puddling, shoring, pumping, &c.

The workmen required for the construction of coffer-dams and similar works are labourers of a superior class, accustomed to the management of pile-engines and tackle, and competent to the execution of such rough carpenter's work as is required in timbering large excavations.

The methods in use of constructing coffer-dams, driving piles, and executing other work connected with foundations, are described in the volume of this series on "Foundations and Concrete Works;" to which the reader is referred for further information on the subject.

BRICKLAYER.

188. The business of a bricklayer consists in the execution of all kinds of work in which brick is the principal material; and in London it always includes tiling and paving with bricks or tiles. Where undressed stone is much used as a building material, the bricklayer executes this kind of work also, and in the country, the business of the plasterer is often united with the above-named branches.

189. The tools of the bricklayer are the *trowel*, to take up

and spread the mortar, and to cut bricks to the requisite length: the *brick axe*, for shaping bricks to any required bevel; the *tin saw*, for making incisions in bricks to be cut with the axe, and a *rubbing-stone*, on which to rub the bricks smooth after being roughly axed into shape. The *jointer* and the *jointing-rule* are used for *running* the centres of the mortar-joints The *raker*, for raking out the mortar from the joints of old brickwork previous to re-pointing. The *hammer*, for cutting chases and splays. The *banker* is a piece of timber about 6 feet long, raised on supports to a convenient height to form a table on which to cut the bricks to any required gauge, for which *moulds* and *bevels* are required. The *crowbar*, *pick-axe*, and *shovel* are used in digging out the foundations, and the *rammer* in punning the ground round the footings, and in rendering the foundation firm where it is soft by beating or ramming.

To set out the work and to keep it true, the bricklayer uses the *square*, the *level*, and the *plumb-rule;* for circular or battering work he uses *templets* and *battering-rules; lines* and *pins* are used to lay the courses by; and *measuring-rods* to take dimensions. When brickwork has to be carried up in conjunction with stonework, the height of each course must be marked on a *gauge-rod*, that the joints of each may coincide.

190. The bricklayer is supplied with bricks and mortar by a labourer, who carries them in a *hod*. The labourer also makes the mortar, and builds and strikes the scaffolding.

191. The bricklayer's scaffold is constructed with *standards*, *ledgers*, and *putlogs*. The standards are fir poles, from 40 to 50 ft. long, and 6 or 7 in. diameter at the butt ends, which are firmly bedded in the ground. When one pole is not sufficiently long, two are lashed together, top and butt, the lashings being tightened with wedges. The ledgers are horizontal poles placed parallel to the walls, and lashed to the standards for the support of the putlogs. The putlogs are cross pieces usually made of birch, and about 6 ft. long, one end resting in the wall, the

other on a ledger. On the putlogs are placed the scaffold boards, which are stout boards hooped at the ends to prevent them from splitting.

192. A bricklayer and his labourer will lay in a single day about 1000 bricks, or about two cubic yards.

193. The tools required for tiling are—the *lathing-hammer*, with two gauge marks on it, one at 7, and the other at 7½ inches; the *iron lathing staff*, to clinch the nails; the *trowel*, which is longer and narrower than that used for brickwork; the *bosse*, for holding mortar and tiles, with an iron hook to hang it to the laths or to a ladder; and the *striker*, a piece of lath about 10 in. long, for clearing off the superfluous mortar at the feet of the tiles.

194. Brickwork is measured and valued by the rod, or by the cubic yard, the price including the erection and use of scaffolding, but not centering to arches, which is an extra charge.

Bricknogging, pavings, and facings, by the superficial yard.

Digging and steining of wells and cesspools by the foot in depth, according to size, the price increasing with the depth.

Plain tiling and pantiling are valued per square of 100 feet superficial.

A journeyman bricklayer receives from 4*s.* to 5*s.* 6*d.*, and a labourer from 2*s.* 6*d.* to 3*s.* 6*d.* a day.

The following memoranda may be useful:—

Weight of different kinds of Earth.

13	cubic feet of	chalk	weigh one ton.
17	,,	clay	,,
18	,,	nightsoil	,,
21¾	,,	gravel	,,
23½	,,	sand	,,

Nightsoil is removed in carts containing 45 cubic feet, or 2½ tons.

Twenty-seven cubic feet or 1 cubic yard is called a single load, and 2 cubic yards a double load

A measure of lime is 27 cubic feet and contains 21 striked bushels.

A bricklayer's hod measures 1 ft. 4 in. × 9 in. × 9 in.. and contains 20 bricks.

A rod of brickwork measures 16½ ft. square, 1½ brick thick (which is called the reduced or standard thickness), or 272 ft. 3 in. superficial, or 306 cubic feet, or 11⅓ cubic yards.

Table of the Sizes and Weights of various Articles.

Description.	Length.		Breadth.		Thickness.		Weight.	
	ft.	in.	ft.	in.	ft.	in.	lbs.	oz.
Stock bricks . . each	0	8¾	0	4¼	0	2½	5	0
Paving do. . . . „	0	9	0	4½	0	1¾	4	0
Dutch clinkers . . „	0	6¼	0	3	0	1½	1	8
12-in. paving tiles . „	0	11¾	0	11¾	0	1½	13	0
10-in. do. . . „	0	9¾	0	9¾	0	1	8	9
Pantiles . . . „	1	1½	0	9½	0	0½	5	4
Plain tiles . . . „	0	10½	0	6½	0	0⅝	2	5
Pantile laths per 10 ft. bundle	120	0	0	1½	0	1	4	6
Do. „ 12 ft. do.	144	0	0	1½	0	1	5	0
N.B.—A bundle contains twelve laths.								
Plain tile lathes per bundle .	500	0	0	1	0	0¼	3	0
N.B.— Thirty bundles of laths make a load.								

A rod of brickwork, laid four courses to a foot in height, requires 4353 stock bricks.

Ditto, 11½ in. to 4 courses, 4533 stock bricks.

These calculations are made without allowing for waste, which is unnecessary, because the space occupied by flues, bond timber, &c., and for which no deduction is made, more than compensates for any waste; and in building dwelling-houses, 4300 stocks to a rod is sufficient.

If laid dry, 5370 stocks to the rod.

4900 ditto, in wells and circular cesspools.

A rod of brickwork, laid 4 courses to gauge 12 in., contains 235 cubic feet of bricks and 71 cubic feet of mortar, and weighs about 15 tons.

A rod of brickwork requires 1½ cubic yard of chalk lime and 3 single loads of sand, or 1 cubic yard of stone lime

and $3\frac{1}{2}$ loads of sand, or 36 bushels of cement and an equal quantity of sharp sand.

A cubic yard of mortar requires 9 bushels of lime and 1 load of sand.

Lime and sand, and likewise cement and sand, lose $\frac{1}{3}$ of their bulk when made into mortar.

The proportion of mortar or cement, when made up, to the lime or cement and sand before made up, is as 2 to 3.

Lime or cement and sand to make mortar require as much water as is equal to $\frac{1}{3}$ of their bulk.

A cubic yard of concrete requires 34 cubic feet of material; or, if the gravel is to the lime as 6 to 1, a cubic yard of concrete will require 1·1 cubic yard of gravel and sand and 3 bushels of lime.

Facing requires 7 bricks per foot superficial

Gauged arches, 10 ditto ditto.

Bricknogging per yard superficial requires 30 bricks on edge, or 45 laid flat.

195. *Paving*:—

Stock bricks laid flat	require	36	per yard superficial.
Ditto on edge	,,	52	,,
Paving bricks laid flat	,,	36	,,
Ditto on edge	,,	82	,,
Dutch clinkers ditto	,,	140	,,
12-inch paving tiles	,,	9	,,
10-inch ditto	,,	13	,,

196. *Tiling*:—

Description.	Gauge in Inches.	No. required per square.
With pantiles	12	150
Ditto	11	164
Ditto	10	180

N.B.—A square of pantiling requires 1 bundle of laths and $1\frac{1}{4}$ hundred of sixpenny nails.

Description.	Gauge in Inches.	No. required per square.
With plain tiles	4	600
Ditto	3½	700
Ditto	3	800
N.B. A square of plain tiling requires 1 bundle of laths, 1 peck of tile pins, and 3 hods of mortar		
Plain tiles laid flat .		210

MASON.

197. The business of the mason consists in *working* the stones to be used in a building to their required shape, and in *setting* them in their places in the work. Connected with the trade of the mason are those of the *Stonecutter*, who *hews* and cuts large stones roughly into shape preparatory to their being *worked* by the mason, and of the *Carver*, who executes the ornamental portions of the stone-work of a building, as enriched cornices, capitals, &c.

198. Where the value of stone is considerable, it is sent from the quarry to the building in large blocks, and cut into slabs and scantlings of the required size with a stone-mason's saw, which differs from that used in any other trade in having no teeth. It is a long thin plate of steel, slightly jagged on the bottom edge, and fixed in a frame; and, being drawn backwards and forwards in a horizontal position, cuts the stone by its own weight. To facilitate the operation, a heap of sharp sand is placed on an inclined plane over the stone, and water allowed to trickle through it, so as to wash the sand into the saw-cut. Of late years machinery worked by steam-power has been used for sawing marble into slabs to a very great extent, and has almost entirely superseded manual labour in this part of the manufacture of chimney-pieces.

Some freestones, as Bath-stone, are so soft as to be easily cut with a toothed saw worked backwards and forwards by two persons.

The harder kinds of stones, as granites and gritstones, are brought roughly into shape at the quarry, with an axe or a scappling hammer, and are then said to be *scappled.*

199. The tools used by the mason for cutting stone consists of the *mallet* and *chisels* of various sizes. The mason's mallet differs from that used by any other artisan, being similar to a dome in contour, excepting a portion of the broadest part, which is rather cylindrical; the handle is short, being only sufficiently long to enable it to be firmly grasped.

In London the tools used to work the faces of stone are the *point*, which is the smallest description of chisel, being never more than a quarter of an inch broad on the cutting edge; the *inch tool;* the *boaster*, which is 2 in. wide; and the *broad tool*, of which the cutting edge is $3\frac{1}{2}$ in. wide. The tools used in working mouldings and in carving are of various sizes, according to the nature of the work.

Besides the above cutting tools the mason uses the *banker* or bench, on which he places his stone for convenience of working, and *straight edges*, *squares*, *bevels*, and *templets* for marking the shapes of the blocks, and for trying the surfaces as the work proceeds. Any angle greater or less than a right angle is called a bevel angle, and a *bevel* is formed by nailing two straight edges together at the required angle; a *bevel square* is a square with a shifting stock which can be set to any required bevel. A templet is a pattern for cutting a block to any particular shape; when the work is moulded the templet is called a *mould.* Moulds are commonly made of sheet zinc, carefully cut to the profile of the mouldings with shears and files.

For setting his work in place the mason uses the *trowel*, *lines, and pins*, the *square* and *level*, and *plumb* and *battering rules*, for adjusting the faces of upright and battering walls.

200. The mason's scaffold is double, that is, formed with two rows of standards, so as to be totally independent of the walls for support, as putlog holes are inadmissible in masonry.

During the last ten years the construction of scaffolds, with round poles lashed with cords has been entirely superseded in large works by a system of scaffolding of square timbers connected by bolts and dog irons.

The hoisting of the materials is performed from these scaffolds by means of a travelling crane, which consists of a double travelling carriage running on a tramway formed on stout sills laid on the top of two parallel rows of standards. The crab-winch is placed on the upper carriage, and, by means of the double motion of the two carriages, can be brought with great ease and precision over any part of the work lying between the two rows of standards.

The facilities which are afforded by these scaffolds and travelling cranes for moving heavy weights over large areas, have led to their extensive adoption, not only in the erection of buildings, but on landing wharfs, masons and iron-founders' yards, and similar situations, where a great saving of time and labour is effected by their use.

Scaffolding of square timbers appears to have been little used in England before A.D. 1837, when Messrs. Cubitt, of Gray's Inn Road, applied it to the erection of the entrance gateway of the Euston station of the North-Western Railway. Since then it has been very generally used in large works, amongst which may be mentioned the Reform Club House, in A.D. 1838, and the Nelson Column, commenced A.D. 1840, where it was carried up in perfect safety to the height of 180 feet; and it has been used on a very large scale at the New Houses of Parliament now in progress.

Although of modern introduction in England this kind of scaffolding is not a new invention. It appears to have been used at Cologne Cathedral from the first commencement of that building in A.D. 1248. It was also used by Domenic Fontana in A.D. 1586, for erecting the Egyptian Obelisk in front of St. Peter's at Rome; and similar scaffolding was used in Paris in our own times, in erecting the Arc de l'Etoile, and the Eglise de la Madeleine.

201 The moveable derrick crane is also much used in setting mason's work. It consists of a vertical post, supported by two timber backstays, and a long moveable jib or derrick hinged against the post below the gearing.

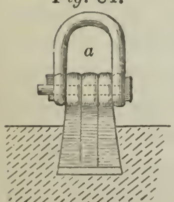
By means of a chain passing from a barrel over a pulley at the top of the post, the derrick can be raised to an almost vertical, or lowered to an almost horizontal position, thus enabling it to command every part of the area of a circle of a radius nearly equal to the length of the derrick. This gives it a great advantage over the old gibbet crane, which only commands a circle of a fixed radius, and the use of which entails great loss of time from its constantly requiring to be shifted as the work proceeds.

Derrick cranes appear to have been first introduced at Glasgow, A.D. 1833, by Mr. York, since which their original construction has been very greatly improved upon, and they are now very extensively used.

202. In hoisting blocks of stone they are attached to the tackle by means of a simple contrivance called a *lewis*, which is shown in fig. 84.

A tapering hole having been cut in the upper surface of the stone to be raised, the two side pieces of the lewis are inserted and placed against the sides of the hole; the centre parallel piece *a* is then inserted and secured in its place by a pin passing through all three pieces, and the stone may then be safely hoisted, as it is impossible for the lewis to draw out of the hole. By means of the lewis, in a slightly altered form from that here shown, stones can be lowered and set under water without difficulty, the lewis being disengaged by means of a line attached to the parallel piece; the removal of which allows the others to be drawn out of the mortice.

Fig. 84.

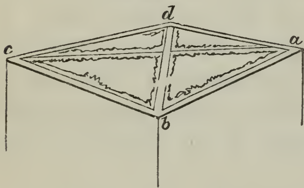


203 In stone-cutting, the workman forms as many plane

faces as may be necessary for bringing the stone into the required shape, with the least waste of material and labour, and on the plane surfaces so formed applies the moulds to which the stone is to be worked.

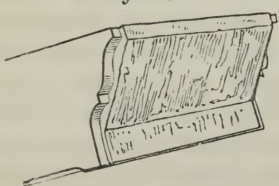
To form a plane surface, the mason first knocks off the superfluous stone along one edge of the block, as *a*, *b* (fig. 85), until it coincides with a straight edge throughout its whole length; this is called a *chisel draught*. Another chisel draught is then made along one of the adjacent edges, as *b*, *c*, and the ends of the two are connected by another draught, as *a*, *c*; a fourth draught is then sunk across the last, as *b*, *d*, which gives another angle point *d*, in the same plane with *a*, *b*, and *c*, by which the draughts *d a* and *a c* can be formed; and the stone is then knocked off between the outside draughts until a straight edge coincides with its surface in every part.

Fig. 85



To form cylindrical or moulded surfaces curved in one direction only, the workman sinks two parallel draughts at the opposite end of the stone to be worked, until they coincide with a mould cut to the required shape, and afterwards works off the stone between these draughts, by a straight edge applied at right angles to them (fig. 86).

Fig. 86.



The formation of conical or spherical surfaces is much less simple, and requires a knowledge of the scientific operations of stone-cutting, a description of which would be unsuited to the elementary character of these pages. The reader who wishes to pursue the subject is therefore referred to the volume of this series on "Masonry and Stone-cutting," where he will find the required information

204. The finely-grained stones are usually brought to a smooth face, and rubbed with sand to produce a perfectly even surface.

In working soft stones, the surface is brought to a smooth face with the *drag*, which is a plate of steel, indented on the edge like the teeth of a saw, to take off the marks of the tools employed in shaping it.

The harder and more coarsely-grained stones are generally *tooled*, that is, the marks of the chisel are left on their face. If the furrows left by the chisel are disposed in regular order, the work is said to be *fair-tooled*, but if otherwise, it may be *random-tooled*, or *chiselled*, or *boasted*, or *pointed*. If the stones project beyond the joints, the work is said to be *rusticated*.

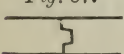
Granite and gritstone are chiefly worked with the scappling hammer. In massive erections, where the stones are large, and a bold effect is required, the fronts of the blocks are left quite rough, as they come out of the quarry, and the work is then said to be *quarry pitched*.

Many technical terms are used by quarrymen and others engaged in working stone; but they need not be inserted here, as they are mostly confined to particular localities, beyond which they are little known, or perhaps bear a different signification.

205. When the mason requires to give to the joints of his work greater security than is afforded by the weight of the stone and the adhesion of the mortar, he makes use of *joggles*, *dowels*, and *cramps*.

Stones are said to be joggled together when a projection is worked out on one stone to fit into a corresponding hole or groove in the other (*see* fig. 87). But this occasions great labour and waste of stone, and *dowel-joggles* are chiefly made use of, which are hard pieces of stone, cut to the required size, and let into corresponding mortices in the two stones to be joined together.

Fig. 87.



Dowels are pins of wood or metal used to secure the

joints of stone-work in exposed situations, as copings, pinnacles, &c. The best material is copper; but the expense of this metal causes it to be seldom used. If iron be made use of, it should be thoroughly tinned to prevent oxidation, or it will, sooner or later, burst and split the work it is intended to protect.

Dowels are often secured in their places with lead poured in from above, through a small channel cut in the side of the joint for that purpose; but a good workman will eschew lead, which too often finds its way into bad work, and will prefer trusting to very close and workmanlike joints, carefully fitted dowels, and fine mortar; dowels should be made tapering at one end, which ensures a better fit, and renders the setting of the stone more easy for the workman.

Iron cramps are used as fastenings on the tops of copings, and in similar situations; but they are not to be recommended, as they are very unsightly, and, if they once become exposed to the action of the stmosphere, are powerfully destructive agents. Cast iron is, however, less objectionable than wrought iron for this purpose.

206. In measuring mason's work, the cubic content of the stone is taken as it comes to the *banker*, without deduction for subsequent waste.

If the scantlings are large, an extra price is allowed for hoisting.

The labour in working the stone is charged by the superficial foot, according to the kind of work, as plain work, sunk work, moulded work, &c.

Pavings, landings, &c., and all stone less than 3 in. thick, are charged by the superficial foot.

Copings, curbs, window sills, &c., are charged per lineal foot.

Cramps, dowels, mortice holes, &c., are always charged separately.

A journeyman mason will receive from 4*s.* to 5*s.* 6*d.* per day, and the labourer from 2*s.* 6*d.* to 3*s.* per day; but

masons working at piece-work, or at any work requiring particular skill, will often earn much more.

The remuneration of a stone-carver is dependent on his talent, and the kind of work he is engaged upon.

The following table of the weights of different kinds of stone will convey an idea of their relative hardness, and of the labour required to work them.

Table of the Weights of different kinds of Stone

13	cubic feet of	marble	weigh one ton
13½	„	granite	„
14	„	Purbeck stone	„
14¼	„	Yorkshire stone	„
16	„	Derbyshire grit	„
17	„	Portland stone	„
18	„	Bath stone	„

Mem.—58 ft. superficial of 3-in. York paving weigh one ton

70 ft. superficial of 2½-in. York paving weigh one ton

CARPENTER

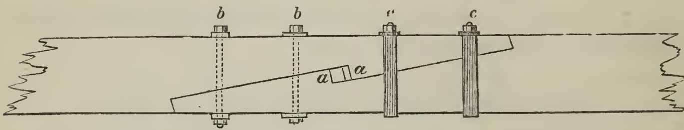
207. The business of the carpenter consists in framing timbers together, for the construction of roofs, partitions, floors, &c.

208. The carpenter's principal tools are the axe, the adze, the saw, and the chisel, to which may be added the chalk-line, plumb-rule, level, and square. The work of the carpenter does not require the use of the plane, which is one of the principal tools of the joiner, and this forms the principal distinction beween these trades, the carpenter being engaged in the rough framework, and the joiner on the finishings and decorations of buildings.

209. The principles of framing have been already fully described in the 1st section of this work, and we shall therefore confine our remarks on the operations of the carpenter to a description of the principal joints made use of in framing.

Timbers that have to be joined in the direction of their length are *scarfed*, as shown in fig. 88; the double wedges, *a a*, serve to bring the timbers *home*, when they are secured,

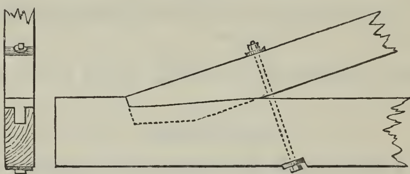
Fig. 88.



either by bolts, as shown at *b b*, or by straps, as at *c c*, the latter being the most perfect and the most expensive fastening.

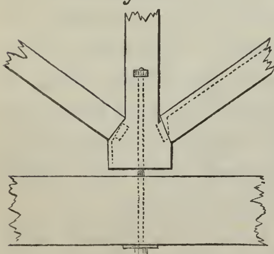
Fig. 89 shows the manner of connecting the foot of a principal rafter with a tie-beam The bolt here shown

Fig. 89.



keeps the rafter in its place, and prevents it from slipping away from the abutment cut for it, which, by throwing the thrust on the tenon, would probably split it. The end of the rafter should be cut with a square butt, so that the shrinkage of the timber will not lead to any settlement.

Fig. 90.



The connection of the foot of a king-post with the tie beam to be suspended from it is shown in fig. 90.

The king-post should be cut somewhat short, to give the power of screwing up the framing after the timber has

become fully seasoned. The tie-beam may be suspended from the king-post, either by a bolt, as shown, or by a strap passed round the tie-beam and secured by iron wedges or cotters, passing through a hole in the king-post; this last is the more perfect, but at the same time the more expensive of the two methods.

Fig. 90 also shows the manner in which the feet of the struts butt upon the king-post. They are slightly tenoned to keep them in their places. The ends of a strut should be cut off as nearly square as possible, otherwise, when the timber shrinks, which it will always do, more or less, the thrust is thrown upon the edge only, which splits or crushes under the pressure, and causes settlement.

This is shown out by the dotted lines on the right-hand side of the cut. The dotted lines on the opposite side of the figure show a similar effect, produced by the shrinking of the king-post, for which there is no preventative but making it of oak, or some other hard wood. The same observations apply to the connections of the principal rafters with the top of the king-post, which are managed in a precisely similar manner.

In figures 91, 92, and 93, are shown different methods

Fig. 91.

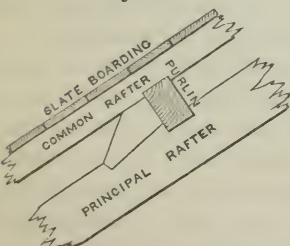
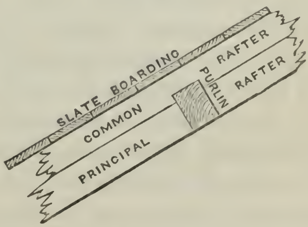


Fig. 92.

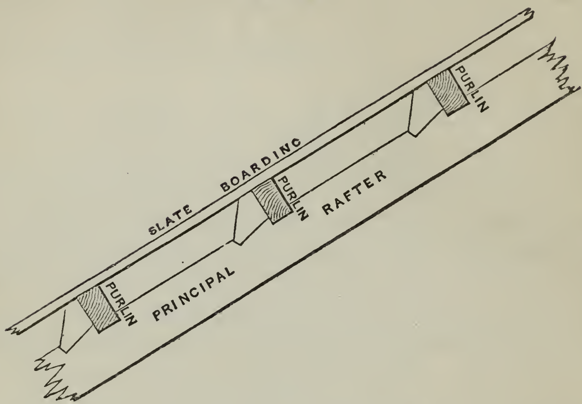


of fixing purlins, which are sufficiently explained by the figures to need no further description.

In figures 46, 47, 48, and 49, are shown the modes of framing the ends of binding joists into girders, and of connecting the ceiling joists with the binders; and as these

have been already described under the head of "Floors,"

Fig 93.



it is unnecessary here to say anything further on the subject.

As a general rule, all timbers should be notched down to those on which they rest, so as to prevent their being moved either lengthways or sideways. Where an upright post has to be fixed between two horizontal sills, as in the case of the uprights of a common framed partition, it is simply tenoned into them, and the tenons secured with oak pins driven through the cheeks of the mortice.

210. The carpenter requires considerable bodily strength for the handling of the timbers on which he has to work; he should have a knowledge of mechanics, that he may understand the nature of the strains and thrusts to which his work is exposed, and the best method of preventing or resisting them; and he should have such a knowledge of working drawings as will enable him, from the sketches of the architect, to set out the *lines* for every description of centering and framing that may be entrusted to him for execution.

211. In measuring carpenters' work the tenons are included in the length of the timber· this is not the case

in joiners' work, in which they are allowed for in the price

The labour in framing, roofs, partitions, floors, &c., is either valued at per square of 100 superficial feet, and the timber charged for separately, or the timber is charged as "fixed in place," the price varying according to the labour on it, as "cube fir in bond," "cube fir framed," "cube fir wrought and framed," &c. For shoring $\frac{1}{3}$ of the value of the timber is allowed for use and waste.

The wages of a journeyman carpenter are from 4*s*. to 5*s*. 6*d*. per day.

JOINER.

212. The work of the joiner consists in framing and *joining* together the wooden finishings and decorations of buildings, both internal and external, such as floors, stair cases, framed-partitions, skirtings, solid door and window frames, hollow or *cased* window frames, sashes and shutters, doors, columns and entablatures, chimney-pieces, &c., &c.

The joiner's work requires much greater accuracy and finish than that of the carpenter, and differs materially from it in being brought to a smooth surface with the plane wherever exposed to view, whilst in carpenters' work the timber is left rough as it comes from the saw.

213. The joiner uses a great variety of tools; the principal *cutting* tools are *saws*, *planes*, and *chisels.*

Of saws there are many varieties, distinguished from each other by their shape and by the size of the teeth.

The *ripper* has 8 teeth in 3 inches; the *half-ripper* 3 teeth to the inch; the *hand saw* 15 teeth in 4 inches; the *panel saw* 6 teeth to the inch.

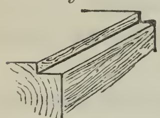
The *tenon saw*, used for cutting tenons, has about 8 teeth to the inch, and is strengthened at the back by a thick piece of iron, to keep the blade from buckling. The *sash saw* is similar to the tenon saw, but is backed with brass instead of iron, and has 13 teeth to the inch. The *dovetail saw* is still smaller, and has 15 teeth to the inch.

Besides the above, other saws are used for particular purposes, as the *compass saw*, for cutting circular work, and the *key-hole saw*, for cutting out small holes. The *carcase saw* is a large kind of dovetail saw, having about 11 teeth to an inch.

214. Planes are also of many kinds; those called *bench planes*—as the *jack plane*, the *trying plane*, the *long plane*, the *jointer*, and the *smoothing plane*, are used for bringing the stuff to a plane surface. The jack plane is about 18 in. long, and is used for the roughest work. The trying plane is about 22 in. long, and used after the jack plane for *trying up*, that is, taking off shavings the whole length of the stuff; whilst in using the jack plane the workman stops at every arm's-length. The *long plane* is 2 ft. 3 in. long, and is used when a piece of stuff is to be tried up very straight. The *jointer* is 2 ft. 6 in. long, and is used for trying up or *shooting* the *joints*, in the same way as the trying plane is used for trying up the *face* of the stuff. The *smoothing plane* is small, being only 7½ in. long, and is used on almost all occasions for cleaning off finished work.

Rebate planes are used for sinking *rebates* (*see* fig. 94), and vary in their size and shape according to their respective uses. Rebate planes differ from bench planes in having no handle rising out of the stock, and in discharging their shavings at the side. Amongst the rebate planes may be mentioned the *moving fillister* and the *sash fillister*, the uses of which will be better understood by inspection than from any description.

Fig. 94.



Moulding planes are used for *sticking* mouldings, as the operation of forming mouldings with the plane is called. When mouldings are worked out with chisels instead of with planes, they are said to be worked *by hand*. Of the class of moulding planes, although kept separate in the tool chest, are *hollows* and *rounds* of various sizes.

There are other kinds of planes besides the above; as the *plough*, for sinking a groove to receive a projecting

tongue; the *bead plane*, for sticking beads; the *snipe bill*, for forming quirks; the *compass plane* and the *forkstaff plane*, for forming concave and convex cylindrical surfaces. The shape and use of these and many other tools used by the joiner will be better understood by a visit to the joiner's shop than by any verbal description.

215. Chisels are also varied in their form and use. Some are used merely with the pressure of the hand, as the *paring chisel;* others, by the aid of the mallet, as the *socket chisel,** for cutting away superfluous stuff; and the *mortice chisel*, for cutting mortices. The *gouge* is a curved chisel.

216. The joiner uses a great variety of boring tools, as the *brad-awl*, *gimlet*, and *stock and bit.* The last form but one tool, the *stock* being the handle, to the bottom of which may be fitted a variety of steel bits of different bores and shapes, for boring and widening out holes in wood and metal, as *countersinks*, *rimers*, and *taper shell bits.*

217. The *screw-driver*, *pincers*, *hammer*, *mallet*, *hatchet*, and *adze*, are too well known to need description.

The *gauge* is used for drawing lines on a piece of stuff parallel to one of its edges.

The *bench* is one of the most important of the joiner's implements. It is furnished with a vertical *sideboard*, perforated with diagonal ranges of holes, which receive the *bench pin* on which to rest the lower end of a piece of stuff to be planed, whilst the upper end is firmly clamped by the *bench screw.*

The *mitre box* is used for cutting a piece of stuff to a *mitre* or angle of 45 degrees with one of its sides.

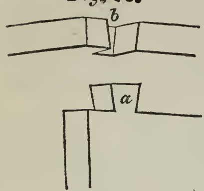
The joiner uses for setting out and fixing his work—the straight edge, the square, the bevel or square with a shifting blade, the mitre square, the level, and the plumb rule.

In addition to the tools and implements above enumerated, the execution of particular kinds of work requires

* Named from the iron forming a socket to receive a wooden handle.

other articles, as cylinders, templets, cramps, &c., the description of which would unnecessarily extend the limits of this volume

Fig. 95.

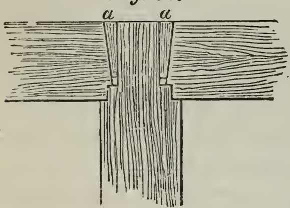


218. The principal operations of the joiner are sawing, planing, dovetailing, mortising, and scribing.

The manner of forming a *dovetail* is shown in fig. 95. The projecting part, *a*, is called the *pin*, and the hole to receive it is called the *socket.*

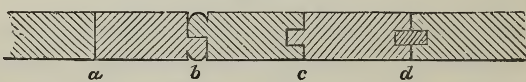
Mortising is shown in fig. 96; the projecting piece is called the *tenon*, and the hole formed to receive it the *mortice.* The tenon is sometimes *pinned* in its place with oak pins driven through the cheeks of the mortice; but in forming doors, shutters, &c., the tenon is secured with tapering wedges driven into the mortice, which is cut slightly wider at the top than at the bottom, the adhesion of the glue with which the wedges are first rubbed over, making it impossible for the tenon afterwards to draw out of its place.

Fig. 96.



219. Joints in the length of the stuff may be either square, as at *a*, fig. 97, or rebated, as at *b*, or grooved and

Fig. 97.



tongued, as at *c*, or grooved on each edge and a tongue let in, as at *d*

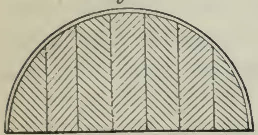
220. *Scribing* is the drawing on a piece of stuff the exact profile of some irregular surface to which it is to be made to fit: this is done with a pair of compasses, one leg of which is made to traverse the irregular surface, the other to

describe a line parallel thereto along the edge of the stuff to be cut.

221. In the execution of circular, or, as it is termed, *sweep work*, there are four different methods by which the stuff can be brought to the required curve:—

1st. It may be steamed and bent into shape

Fig. 98.



2nd. It may be glued up in thicknesses, as shown in fig. 98, which must, when thoroughly dry, be planed true, and, if not to be painted, covered with a thin veneer bent round it.

3rd. It may be formed in thin thicknesses, as shown in fig 99, bent round and glued up in a mould. This may be considered the most perfect of all the methods in use

Fig. 99.

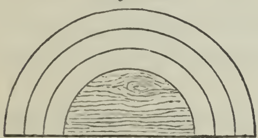
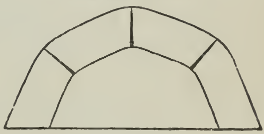


Fig. 100.



Lastly. It may be formed by sawing a number of notches on one side, as shown in fig. 100, by which means it becomes easily bent in that direction, but the curve produced by this means is very irregular, and it is an inferior mode of execution compared to the others.

Fig. 101.

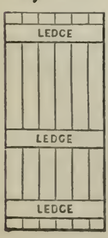
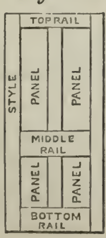


Fig. 102.



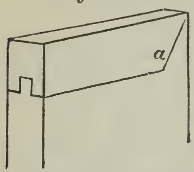
222. When a number of boards are secured together by cross-pieces or *ledges* nailed or screwed at the back, the work is said to be *ledged* (*see* fig. 101). Ledged work is used for common purposes, as cellar doors, outside shutters, &c.

Framed work (fig. 102) consists of *styles* and *rails* mortised and tenoned

together, and filled in with pannels, the edges of which fit in grooves cut for that purpose in the styles and rails.

Work is said to be *clamped* when it is prevented from warping or splitting by a rail at each end, as in fig. 103; if the ends of the rail are cut off, as shown at *a*, it is said to be mitre clamped.

Fig. 103.



223. There are two ways of laying floors practised by joiners. In laying what is called a *straight joint* floor, from the joints between the boards running in an unbroken line from wall to wall, each board is laid down and nailed in succession, being first forced firmly against the one last laid with a flooring cramp.

Folding floors are laid by nailing down first every fifth board rather closer together than the united widths of four boards, and forcing the intermediate ones into the space left for them by jumping upon them; this method of laying floors is resorted to when the stuff is imperfectly seasoned and is expected to shrink, but it should never be allowed in good work.

The narrower the stuff with which a floor is laid the less will the joints open, on account of the shrinkage being distributed over a greater number of joints.

The floor boards may be nailed at their edges, and grooved and tongued or dowelled, if it be wished to make a very perfect floor. Dowelling is superior to grooving and tonguing, because the cutting away the stuff to receive the tongue greatly weakens the edges of the joint, which are apt to curl

224. Glue is an article of great importance to the joiner; the strength of his work depending much upon its adhesive properties.

The best glue is made from the *skins* of animals; that from the *sinewy* or *horny* parts being of inferior quality. The strength of the glue increases with the age of the animals from which the skins are taken.

225. Joiners' work is measured by the superficial foot, according to its description.

Floors by the square of 100 superficial feet.

Handrails, small mouldings, water-trunks, and similar articles, per lineal foot.

Cantilevers, trusses, cut brackets, scrolls to handrails, &c., are valued per piece.

The wages of a joiner are from 4*s.* to 5*s.* 6*d.* per day.

The following memoranda relative to carpenters' and joiners' work may be found useful.

Weight of Timber.

34	cubic feet of	mahogany	weigh	one ton
39	,,	oak	,,	,,
45	,,	ash	,,	,,
51	,,	beech	,,	,,
60	,,	elm	,,	,,
65	,,	fir	,,	,,

50 cubic feet of timber 1 load.

120 deals = one hundred.

120 12 ft. 3 in. deals = $5\frac{2}{5}$ loads of timber.

400 superficial feet $1\frac{1}{2}$ in. deal = 1 load.

Planks are . .	11 in. wide
Deals	9 ,,
Battens	7 ,,

A reduced deal is $1\frac{1}{2}$ in. thick, 11 in. wide, and 12 feet long.

A square of flooring laid with 12 feet deals requires

Laid rough	$12\frac{1}{4}$	floorboards.
Ditto, edges shot	$12\frac{1}{2}$	,,
Wrought and laid folding . .	13	,,
Ditto, straight joint	$13\frac{1}{2}$	,,
Wrought and laid straight joint, and ploughed and tongued . .	14	,,
If laid with 12 ft. battens,		
Wrought, and laid folding . . .	17	,,
Ditto, ditto, straight joint . .	18	,,

226. *Ironmongery* is charged for with the work to which it is attached; the joiner being allowed 20 per cent. profit upon the prime cost.

The principal articles of ironmongery used in a building consist of *nails* and *screws*, *sash pullies*, *bolts*, *hinges*, *locks*, *latches*, and *sash* and *shutter furniture*, besides a great variety of miscellaneous articles, which we have not space to enumerate.

227. Of the different kinds of hinges may be mentioned *hook* and *eye hinges*, for gates, coach-house doors, &c.; *butts* and *back-flaps*, for doors and shutters; *cross garnets* of ⊢ form, which are used for hanging ledged doors, and other inferior work: H and H— hinges, whose name is derived from their shape; and *parliament* hinges.

Besides these are used *rising butts*, for hanging doors to rise over a carpet, or other impediment; *projecting butts*, used when some projection has to be cleared, and *spring hinges* and *swing centres*, for self-shutting doors.

228. The variety of locks now manufactured is almost infinite. We may mention the *stock lock*, cased in wood, for common work. *Rim locks*, which have a metal case or rim, and are attached to one side of a door: they should not be used when a door has sufficient thickness to allow of a mortice lock, as they often catch the dresses of persons passing through the doorway. *Mortice locks*, as the name implies, are those which are mortised into the thickness of the door.

The handles and escutcheons are called the *furniture* of a lock, and are made of a great variety of materials, as brass, bronze, ebony, ivory, glass, &c.

229. Of latches, there are the common *thumb latch*, the *bow latch*, with brass knobs, the brass *pulpit latch*, and the *mortice latch*.

230. The *sawyer* is to the carpenter and joiner what the stone-cutter is to the mason.

The *pit-saw* is a large two-handed saw fixed in a frame, and moved up and down in a vertical direction, by two men,

called the top-man and the pit-man; the first of whom stands on the timber that is to be cut, the other at the bottom of the saw-pit. The timber is *lined out* with a chalk line on its upper surface, and the accuracy of the work depends mainly on the top-man keeping the saw to the line, whence the proverbial expression *top-sawyer*, meaning one who directs any undertaking.

In sawing up deals and battens into thicknesses for the joiner's use, the parallelism of the cuts is of the utmost importance, as the operation of *taking out of winding*, a piece of uneven stuff, causes a considerable waste of material, and much loss of time.

Circular saws, moved by steam power,* are now much used in large establishments, timber yards, &c., and effect a great saving of labour over the use of the pit saw, where the timbers to be cut are not too heavy to be easily handled. The saw is mounted in the middle of a stout bench, furnished with guides, by means of which the stuff to be cut is kept in the required direction, whilst it is pushed against the saw, which is the whole of the manual labour required in the operation.

SLATER.

231. The business of the slater consists chiefly in covering the roofs of houses with slates, but it has of late years been very much extended by the general introduction of sawn slate, as a material for shelves, cisterns, baths, chimney pieces, and even for ornamental purposes.

We purpose here to describe only those operations of the slater which have reference to the covering of roofs.

232. Besides the tools which are in common use among other artificers, the slater uses one peculiar to his trade, called the *zax*, which is a kind of hatchet, with a sharp point

* The author recently visited a carpenter's shop in a country village in Leicestershire, which was mounted in a very complete manner, with bench and other saws, lathes, &c., all worked by a set of wind-sails on the roof.

at the back. It is used for trimming slates, and making the holes by which they are nailed in their places.

233. Slates are laid either on boarding or on narrow battens, from 2 to 3 inches wide, the latter being the more common method, on account of its being less expensive than the other.

The nails used should be either copper or zinc; iron nails, though sometimes used, being objectionable from their liability to rust.

Every slate should be fastened with two nails, except in the most inferior work.

The upper surface of a slate is called its *back*, the under surface the *bed*, the lower edge the *tail*, the upper edge the *head*. The part of each course of slates exposed to view is called the *margin* of the course, and the width of the margin is called the *gauge*.

The *bond* or *lap* is the distance which the lower edge of any course overlaps the slates of the second course below, measuring from the nail-hole.

In preparing slates for use, the sides and bottom edges are trimmed, and the nail-holes punched as near the head as can be done, without risk of breaking the slate, and at a uniform distance from the tail.

The lap having been decided on, the gauge will be equal to half the distance from the tail to the nail-hole, less the lap. Thus a countess slate, measuring 19 in. from tail to nail, if laid with a 3-in. lap, would show a margin of $\frac{19 \text{ in.} - 3 \text{ in.}}{2} = 8$ in. (*See* figs. 104, 105.)

Fig. 104.

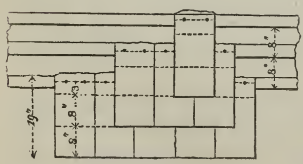
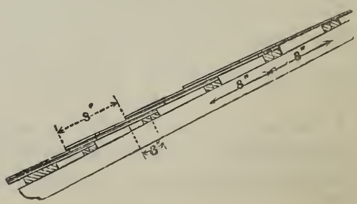


Fig. 105.



The battens are of course nailed on the rafters at the gauge to which the slates will work. If the slates are of different lengths, they must be sorted into sizes, and gauged accordingly, the smallest sizes being placed nearest the ridge. The lap should not be less than 2 in., and need not exceed 3 in.

It is essential to the soundness as well as the appearance of slaters' work, that the slates should all be of the same width, and the edges perfectly true.

The Welsh slates are considered the best, and are of a light sky blue colour. The Westmoreland slates are of a dull greenish hue.

234. Slaters' work is measured by the square of 100 superficial feet, allowances being made for the trouble of cutting the slates at the hips, eaves, round chimneys, &c.

Slabs for cisterns, baths, shelves, and other sawn work, are charged per superficial foot, according to the thickness of the slab, and the labour bestowed on the work.

Rubbed edges, grooves, &c., are charged per lineal foot.

Table of the Sizes of Roofing Slates.

Description.	Size. Length. ft.	Size. Length. in.	Size. Breadth. ft.	Size. Breadth. in.	Average gauge in inches.	No. of squares 1200 will cover.	Weight per 1200 in tons.	No. required to cover one square.	No. of nails required to one square.
Doubles . . .	1	1	0	6	$5\frac{1}{2}$	2	$\frac{3}{4}$	480	480
Ladies . . .	1	4	0	8	7	$4\frac{1}{2}$	$1\frac{1}{4}$	280	280
Countesses . .	1	8	0	10	9	7	2	176	352
Duchesses . .	2	0	1	0	$10\frac{1}{2}$	10	3	127	254
Imperials . .	2	6	2	0	a ton will cover $2\frac{1}{4}$ to $2\frac{1}{2}$ squares.				
Rags and Queens	3	0	2	0					
Westmorelands, of various sizes					do.	do.	2	do.	

Inch slab per foot superficial weighs 14 lbs.

A journeyman slater receives about 5*s*. per day, and his labourer about 3*s*.

PLASTERER

235. The work of the plasterer consists in covering the brickwork and naked timbers of walls, ceilings, and partitions with plaster, to prepare them for painting, papering, or distempering; and in forming cornices, and such decorative portions of the finishings of buildings as may be required to be executed in plaster or cement.

236. The plasterer uses a variety of tools, of which the following are the principal ones:—

The *drag* is a three-pronged rake, used to mix the hair with the mortar in preparing coarse stuff.

The *hawk* is a small square board for holding stuff on, with a short handle on the under side.

Trowels are of two kinds, the *laying and smoothing tool*, with which the first and the last coats are laid, and the *gauging trowel*, used for gauging fine stuff for cornices, &c.; these are made of various sizes, from 3 to 7 in. long.

Of *floats*, which are used in *floating*, there are three kinds, viz. the *Derby*, which is a rule of such a length as to require two men to use it; the *hand float*, which is used in finishing stucco; and the *quirk float*, which is used in floating angles.

Moulds, for running cornices, are made of sheet copper, cut to the profile of the moulding to be formed, and fixed in a wooden frame.

Stopping and *picking out tools* are made of steel, 7 or 8 in. long, and of various sizes. They are used for modelling, and for finishing mitres and returns to cornices.

237. *Materials.—Coarse stuff*, or lime and hair, as it is usually called, is similar to common mortar, with the addition of hair from the tanner's yard, which is thoroughly mixed with the mortar by means of the drag.

Fine stuff is made of pure lime, slaked with a small quantity of water, after which, sufficient water is added to bring it to the consistence of cream.

It is then allowed to settle, and the superfluous water being poured off, it is left in a binn or tub to remain in a semifluid state until the evaporation of the water has

brought it to a proper thickness for use. In using fine stuff for setting ceilings, a small portion of white hair is mixed with it.

Stucco is made with fine stuff, and clean-washed sand This is used for finishing work intended to be painted.

Gauged stuff is formed of fine stuff mixed with plaster of Paris, the proportion of plaster varying according to the rapidity with which the work is required to set. Gauged stuff is used for running cornices and mouldings.

Enrichments, such as pateras, centre flowers for ceilings, &c., are first modelled in clay, and afterwards cast of plaster of Paris in wax or plaster moulds. Papier maché ornaments also are much used, and have the advantage of being very light, and being easily and securely fixed with screws.

The variety of compositions and cements made use of by the plasterer is very great. Roman cement, Portland cement, and lias cement, are the principal ones used for coating buildings externally. Martin's and Keene's cements are well adapted for all internal plastering where sharpness, hardness, and delicate finish are required.

238. *Operations of Plastering.*—When brickwork is plas tered, the first coat is called *rendering.*

In plastering ceilings and partitions, the first operation is *lathing.* This is done with *single*, *one and a hàlf*, or *double* laths; these names denoting their respective thicknesses Laths are either of oak or fir; if the former, wrought-iron nails are used, but cast-iron nails may be employed with the latter. The thickest laths are used for ceilings, as the strain on the laths is greater in a horizontal than in an upright position.

Pricking up is the first coat of plastering of coarse stuff upon laths; when completed, it is well scratched over with the end of a lath, to form a key for the next coat.

Laid work consists of a simple coat of coarse stuff over a wall or ceiling.

Two-coat work is a cheap description of plastering, in which the first coat is only roughed over with a broom. and after-

wards *set* with fine stuff, or with gauged stuff in the better descriptions of work.

The laying on of the second coat of plastering is called *floating*, from its being *floated*, or brought to a plane surface with the float.

The operation of floating is performed by surrounding the surface to be floated with narrow strips of plastering, called screeds, brought perfectly upright, or level, as the case may be, with the level or plumb-rule; thus, in preparing for floating a ceiling, nails are driven in at the angles, and along the sides, about 10 ft. apart, and carefully adjusted to a horizontal plane, by means of the level. Other nails are then adjusted exactly opposite to the first, at a distance of 7 or 8 in. from them. The space between each pair of nails is filled up with coarse stuff, and levelled with a hand float; this operation forms what are called *dots*. When the dots are sufficiently dry, the spaces between the dots are filled up flush with coarse stuff, and floated perfectly true with a floating rule; this operation forms a *screed*, and is continued until the ceiling is surrounded by one continuous screed, perfectly level throughout. Other screeds are then formed, to divide the work into bays about 8 ft. wide, which are successively filled up flush, and floated level with the screeds.

The screeds for floating walls are formed in exactly the same manner, except that they are adjusted with the plumb-rule instead of the level.

After the work has been brought to an even surface with the floating rule, it is gone over with the hand float, and a little soft stuff, to make good any deficiencies that may appear

The operation of forming screeds and floating work, which is not either vertical or horizontal, as a plaster floor laid with a fall, is analogous to that of taking the face of a stone out of winding with chisel-drafts and straight edges in stone-cutting; the principle being in each case to find three points in the same plane from which to extend operations over the whole surface

Setting.—When the floating is about half dry, the setting or finishing coat of fine stuff is laid on with the smoothing trowel, which is alternately wetted with a brush and worked over with the smoothing tool, until a fine surface is obtained.

Stucco is laid on with the largest trowel, and worked over with the hand float, the work being alternately sprinkled with water, and floated until it becomes hard and compact, after which it is finished by rubbing it over with a dry stock brush.

The water has the effect of hardening the face of the stucco, so that, after repeated sprinklings and trowelings, it becomes very hard, and smooth as glass.

239. The above remarks may be briefly summed up as follows. The commonest kind of work consists of only one coat, and is called *rendering*, on brickwork, and *laying*, if on laths. If a second coat be added, it becomes two-coat work, as *render-set*, or *lath lay* and *set*. When the work is floated, it becomes three-coat work, and is *render*, *float*, and *set*, for brickwork, and *lath*, *lay*, *float*, and *set*, for ceilings and partitions; ceilings being set with fine stuff, with a little white hair, and walls intended for paper with fine stuff and sand; stucco is used where the work is to be painted.

Rough stucco is a mode of finishing staircases, passages, &c., in imitation of stone. It is mixed with a large proportion of sand, and that of a coarser quality than troweled stucco, and is not smoothed, but left rough from the hand float, which is covered with a piece of felt, to raise the grit of the sand, to give the work the appearance of stone.

Rough cast is a mode of finishing outside work, by dashing over the second coat of plastering, whilst quite wet, a layer of rough-cast, composed of well-washed gravel, mixed up with pure lime and water, till the whole is in a semi-fluid state.

Pugging is lining the spaces between floor joists with coarse stuff, to prevent the passage of sound, or between two stones, and is done on laths or rough boarding.

In the midland districts of England, reeds are much used instead of laths, not only for ceilings and partitions, but for floors, which are formed with a thick layer of coarse gauged stuff upon reeds. Floors of this kind are extensively used about Nottingham; and, from the security against fire afforded by the absence of wooden floors, Nottingham houses are proverbially fire-proof.

240. Plasterer's work is measured by the superficial yard; cornices by the superficial foot; enrichments to cornices by the lineal foot; and centre flowers and other decorations at per piece.

MEMORANDA.

The wages of a journeyman plasterer are from 4*s.* to 5*s.* a day; those engaged in modelling and ornamental work will earn much more; a labourer receives from 2*s.* 6*d.* to 3*s.* a day, and a plasterer's boy about 1*s.*

Lathing.—One bundle of laths and 384 nails will cover 5 yards.

Rendering.—187½ yards require 1½ hundred of lime, 2 double loads of sand, and 5 bushels of hair.

Floating requires more labour, but only half as much material as rendering.

Setting.—375 yards require 1½ hundred of lime, and 5 bushels of hair.

Render set.—100 yards require 1½ hundred of lime, 1 double load of sand, and 4 bushels of hair.—Plasterer, labourer, and boy, three days each.

Lath, lay, and *set.*—130 yards of lath, lay, and set, require 1 load of laths, 10,000 nails, 2½ hundred of lime, 1½ double load of sand, and 7 bushels of hair.—Plasterer, labourer, and boy, six days each.

Twenty per cent. profit is allowed on all materials.

SMITH AND IRONFOUNDER.

241. The smith furnishes the various articles of wrought-iron work used in a building; as pileshoes, straps, screw-

bolts, dog-irons, chimney bars, gratings, wrought-iron railing, and wrought-iron balustrades for staircases. Wrought iron was formerly much used for many purposes for which cast iron is now almost exclusively employed; the improvements effected in casting during the present century having made a great alteration in this respect.

The operations of the ironfounder have been described in Section II. of this volume, and therefore we have only here to enumerate some of the principal articles which are furnished by him.

Besides cast-iron columns, girders, and similar articles which are cast to order, the founder supplies a great variety of articles which are kept in store for immediate use; as cast-iron gratings, balconies, rain-water pipes and guttering, air traps, coal plates, stoves, stable fittings, iron sashes, &c.

Both wrought and cast iron work are paid for by weight, except small articles kept in store for immediate use, which are valued per piece.

		lbs.
One cubic foot of	cast iron weighs about	450
Ditto	wrought ,,	475
Ditto	closely hammered	485

242. The *coppersmith* provides and lays sheet copper for covering roofs; copper gutters, and rain-water pipes; washing and brewing coppers; copper cramps and dowels for stonemasons' work; and all other copper work in a building; but the cost of the material in which he works prevents its general use; and the washing copper is frequently the only part of a building which requires the aid of this artificer. Sheet copper is paid for by the superficial foot, according to weight, and pipes and gutters per lineal foot; copper in dowels, bolts, &c., at per pound.

243. *Warming apparatus, steam* and *gas fittings*, and similar kinds of work, are put up by the mechanical engineer, who also manufactures a great variety of articles, which are purchased in parts, and put together and fixed by the plumber, as pumps, taps, water closet apparatus, &c.

244. The *bell-hanger* provides and hangs the bells required for communicating between the different parts of a building, and connects them with their *pulls*, or handles, by means of cranks and wires.

The action of the pull upon the bell should be as direct, and effected with as few cranks, as possible; and the cranks and wires should be concealed from view, both to protect them from injury, and on account of their unsightly appearance.

In all superior work, the wires are conducted along concealed tubes, fixed to the walls before the plasterer's work is commenced. The simplest way of arranging the wires is to carry them up in separate tubes to the roof, where they may all be conducted to one point, and brought down a chase in the walls to the part of the basement where the bells are hung. By this means very few cranks are required, and a broken wire can be replaced at any time without trouble.

245. Bell-hangers' work is paid for by the number of bells hung; the price being determined by the manner in which the work is executed. The *furniture* to the pulls is charged in addition, at per piece.

A journeyman smith receives about 5*s.* a day, and his labourer about 3*s.* 6*d.*; a good bell-hanger will receive 7*s.* a day

PLUMBER.

246. The work of the plumber chiefly consists in laying sheet lead on roofs, lining cisterns, laying on water to the different parts of a building, and fixing up pumps and water closets.

247. The plumber uses but few tools, and those are of a simple character; the greater number of them being similar to those used by other artificers, as *hammers*, *mallets*, *planes*, *chisels*, *gouges*, *files*, &c. The principal tool peculiar to the trade of the plumber is the *bat*, which is made of beech, about 18 in. long, and is used for dressing and flattening sheet lead For soldering also the plumber uses iron

ladles, of various sizes, for melting solder, and *grozing irons*, for smoothing down the joints.

248. The sheet lead used by the plumber is either *cast* or *milled*, the former being generally cast by the plumber himself out of old lead taken in exchange; whilst the latter, which is cast lead, flattened out between rollers in a flatting mill, is purchased from the manufacturer. Sheet lead is described according to the weight per superficial foot, as 5-lb. lead, 6-lb. lead, &c.

Lead pipes, if of large diameter, are made of sheet lead, dressed round a wooden core, and soldered up.

Smaller pipes are cast in short lengths, of a thickness three or four times that of the intended pipe, and either *drawn* or *rolled* out to the proper thickness.

Soft solder is used for uniting the joints of lead-work. It is made of equal parts of lead and tin, and is purchased of the manufacturer by the plumber, at a price per lb., according to the state of the market.

249. *Laying of Sheet Lead.*—In order to secure lead-work from the injurious effects of contraction and expansion, when exposed to the heat of the sun, the plumber is careful not to confine the metal by soldered joints, or otherwise. All sheet lead should be laid to a sufficient *current*, to keep it dry; a fall of 1 in. in 10 ft. is sufficient for this purpose, if the boarding on which the lead is laid be perfectly even Joints in the direction of the current are made by dressing the edges of the lead over a wooden *roll*, as shown in fig. 106.

Joints in the length of the current are made with *drips*, as shown on the left-hand side of fig. 107

Fig. 106.

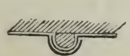
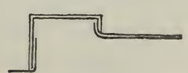


Fig. 107.



Flashings are pieces of lead *turned down* over the edges of other lead-work, which is *turned up* against a wall, as shown on the right-hand side of fig. 107, and serve to keep the wet from finding its way between the wall and the lead

The most secure way of fixing them is to build them into the joints of the brickwork; but the common method is to insert them about an inch into the mortar joint, and to secure them with wall hooks and cement. (*See* fig. 107.)

250. A very important part of the business of the plumber consists in fitting up cisterns, pumps, and water-closet apparatus, and in laying the different services and wastes connected with the same.

251. Plumbers' work is paid for by the cwt., milled lead being rather more expensive than cast.

Lead pipes are charged per foot lineal, according to size.

Pumps and water-closet apparatus are charged at so much each, according to description; as also basins, air traps, washers and plugs, spindle valves, stop-cocks, ball-cocks, &c.

Table of the Weight of Lead Pipes, per yard.

Bore.	lbs.	oz.
$\frac{1}{2}$ inch	3	3
$\frac{3}{4}$,,	5	7
1 ,,	8	0
$1\frac{1}{4}$,,	11	0
$1\frac{1}{2}$,,	14	0
2 ,,	21	0

The wages of a journeyman plumber are from 5*s.* to 6*s.* a day The plumber's labourer receives from 3*s.* to 3*s.* 6*d.* a day

ZINC WORKER.

252. The use of sheet lead has been, to a certain extent, superseded by the use of sheet zinc, which, from its cheapness and lightness, is very extensively used for almost all purposes to which sheet lead is applied. It is, however, a very inferior material, and not to be depended upon. The laying of it is generally executed by the plumber; but the working of zinc, and manufacturing of it into gutters, rain-water pipes, chimney cowls. and other articles, is practised as a distinct business

GLAZIER.

253. The business of the glazier consists in cutting glass, and fixing it into lead-work, or sashes. The former is the

oldest description of glazing, and is still used, not only for cottage windows, and inferior work, but for church windows, and glazing with stained glass, which is cut into pieces of the required size, and set in a leaden framework; this kind of glazing is called *fretwork.*

254. *Glazing in sashes* is of comparatively modern introduction. The sash-bars are formed with a *rebate* on the outside, for the reception of the glass, which is *cut into* the rebates, and firmly *bedded* and *backputtied* to keep it in its place. Large squares are also *sprigged*, or secured with small brads driven into the sash-bars.

255 *Glazing in lead-work* is fixed in leaden rods, called *cames*, prepared for the use of the glazier by being passed through a glazier's vice, in which they receive the grooves for the insertion of the glass. The sides or cheeks of the grooves are sufficiently soft to allow of their being turned down to admit the glass, and again raised up and firmly pressed against it after its insertion.

For common lead-work, the bars are soldered together, so as to form squares or diamonds. In fretwork, the bars, instead of being used straight, are bent round to the shapes of the different pieces of glass forming the device—lead-work is strengthened by being attached to *saddle bars* of iron, by leaden bands soldered to the lead-work, and twisted round the iron.

Putty is made of pounded whiting, beaten up with linseed oil into a tough tenacious cement.

256. The principal tool of the glazier is the *diamond*, which is used for cutting glass. This tool consists of an unpolished diamond fixed in lead, and fastened to a handle of hard wood.

The glazier uses a *hacking-out knife*, for cutting out old putty from broken squares; and the *stopping knife* for laying and smoothing the putty when *stopping-in* glass into sashes.

For setting glass into lead-work, the *setting knife* is used.

Besides the above, the glazier requires a square and

straight edges, a rule, and a pair of compasses, for dividing the tables of glass to the required sizes.

Also a hammer and brushes, for sprigging large squares, and cleaning off the work.

The *glazier's vice* has already been mentioned; the *latterkin* is a pointed piece of hard wood, with which the grooves of the *cames* are cleared out and widened for receiving the glass.

257. Cleaning windows is an important branch of the glazier's business in most large towns; the glazier taking upon himself the cost of repairing all glass broken in cleaning.

258. Glaziers' work is valued by the superficial foot, the price increasing with the size of the squares. Irregular panes are taken of the extreme dimensions each way.

Crown glass is *blown* in circular *tables* from 3 ft. 6 in. to 5 ft. diameter, and is sold in *crates*, the number of tables in a crate varying according to the quality of the glass.

A crate contains		12 tables of		best quality
,,	,,	15	,,	second do.
,,	,,	18	,,	third do.

Plate glass is *cast* in large plates on horizontal tables, and afterwards polished

The manufacture of sheet or spread glass, which was formerly considered a very inferior article, has of late years been much improved: much is now sold, after being polished, under the name of Patent Plate

PAINTER, PAPER-HANGER, AND DECORATOR.

259. The business of the house-painter consists in covering, with a preparation of white lead and oil, such portions of the joiner's, smith's, and plasterer's work as require to be protected from the action of the atmosphere. Decorative painting is a higher branch, requiring a knowledge of the harmony of colours, and more or less of artistic skill, according to the nature of the work to be executed. The introduction of fresco painting into this country as a mode

of internal decoration has led to the employment of some of the first artists of the day in the embellishment of the mansions of the nobility; and the example thus set will, no doubt, be extensively followed.

260. The principal materials used by the painter are *white lead*, which forms the basis of almost all the colours used in house-painting; *linseed oil*, and *spirits of turpentine*, used for mixing and diluting the colours; and *dryers*, as litharge, sugar of lead, and white vitriol, which are mixed with the colours to facilitate their drying. *Putty*, made of whiting and linseed oil, is used for *stopping* or filling up nail holes, and other vacuities, in order to bring the work to a smooth face.

261. The painter's tools are few and simple; they consist of the *grinding stone* and *muller*, for grinding colours; *earthen pots*, to hold colours; *cans*, for oil and turps; a *pallet knife*, and *brushes* of various sizes and descriptions.

262. In painting woodwork, the first operation consists in *killing* the knots, from which the turpentine would otherwise exude and spoil the work. To effect this, the knots are covered with fresh slaked lime, which dries up and burns out the turpentine. When this has been on twenty-four hours, it is scraped off, and the knots painted over with a mixture of red and white lead, mixed with glue size. After this they are gone over a second time with red and white lead, mixed with linseed oil. When dry, they must be rubbed perfectly smooth with pumice stone, and the work is ready to receive the priming coat. This is composed of red and white lead, well diluted with linseed oil. The nail holes and other imperfections are then stopped with putty, and the succeeding coats are laid on, the work being rubbed down between each coat, to bring it to an even surface. The first coat after the priming is mixed with linseed oil and a little turpentine; the second coat with equal quantities of linseed oil and turpentine. In laying on the second coat, where the work is not to be finished white, an approach must be made to the required colour

The third coat is usually the last, and is made with a base of white lead, mixed with the requisite colour, and diluted with one-third of linseed oil to two-thirds of turpentine.

Painting on stucco, and all other work in which the surface is required to be without gloss, has an additional coat mixed with turpentine only, which, from its drying of one uniform *flat* tint, is called a flatting coat.

If the knots show through the second coat, they must be carefully covered with silver leaf.

Work finished as above described would be technically specified as knotted, primed, painted 3 oils, and flatted.

Flatting is almost indispensable in all delicate interior work, but it is not suited to outside work, as it will not bear exposure to the weather

263. Painting on stucco is primed with boiled linseed oil, and should then receive at least three coats of white lead and oil, and be finished with a flat tint. The great secret of success in painting stucco is, that the surface should be perfectly dry; and, as this can hardly be the case in less than two years after the erection of a building, it will always be advisable to finish new work in distemper, which can be washed off whenever the walls are sufficiently dry to receive the permanent decorations.

264. *Graining* is the imitation of the grain of various kinds of woods, by means of *graining tools*, and, when well executed, and properly varnished, has a handsome appearance, and lasts many years. The term graining is also applied to the imitation of marbles.

265. Clear coling (from *claire colle*, i. e. transparent size, Fr.), is a substitution of size for oil, in the preparation of the priming coat. It is much resorted to by painters, on account of the ease with which a good face can be put on the work with fewer coats than when oil is used; but it will not stand damp, which causes it to scale off, and it should never be used except in repainting old work, which is greasy or smoky, and cannot be made to look well by any other means.

266. *Distempering* is a kind of painting in which whiting is used as the basis of the colours, the liquid medium being size; it is much used for ceilings and walls, and always will require two, and sometimes three coats, to give it a uniform appearance.

267. Painters' work is valued per superficial yard, according to the number of coats, and the description of work, as common colours, fancy colours, party colours, &c.

Where work is cut in on both edges, it is taken by the lineal foot In measuring railings, the two sides are measured as flat work. Sash frames are valued per piece, and sashes at per dozen squares

268. The manufacture of scagliola, or imitation marble, is a branch of the decorator's business, which is carried to very great perfection.

Scagliola is made of plaster of Paris and different earthy colours, which are mixed in a trough in a moist state, and blended together until the required effect is produced, when the composition is taken from the trough, laid on the plaster ground, and well worked into it with a wooden beater, and a small gauging trowel. When quite hard, it is smoothed, scraped, and polished, until it assumes the appearance of marble.

Scagliola is valued at per superficial foot, according to the description of marble imitated, and the execution of the work.

269. Gilding is executed with leaf gold, which is furnished by the gold-beater in books of 25 leaves, each leaf measuring $3\frac{1}{8}$ in. by 3 in. The parts to be gilded are first prepared with a coat of gold size, which is made of Oxford ochre and fat oil.

270. The operations of the paper-hanger are too simple to require description.

A piece of paper is 12 yards long, and is 20 in. wide, when hung, and covers 60 ft. superficial; hence the number of superficial feet that have to be covered, divided by 60, will give the number of pieces required.

Paper-hangers' work is valued at per piece, according to the value of the paper

The trades of the plumber, glazier, painter, paper-hanger, and decorator are often carried on by the same person

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SECTION V.

WORKING DRAWINGS, SPECIFICATIONS, ESTIMATES, AND CONTRACTS.

271. The erection of buildings of any considerable magnitude is usually carried on under the superintendence of a professional architect, whose duties consist in the preparation of the various working drawings and specifications that may be required for the guidance of the builder; in the strict supervision of the work during its progress, to insure that his instructions are carried out in a satisfactory manner; and in the examination and revision of all the accounts connected with the works.

This brief enumeration of the duties of an architect will suffice to show how many qualifications are required in one who aims at being thoroughly competent in his profession He must unite the taste of the artist with the science and practical knowledge of the builder, and must be at the same time conversant with mercantile affairs, and counting-house routine, in order that he may avoid involving his employer in the trouble and expense attendant on disputed accounts, which generally are the result of the want of a clear and explicit understanding, on the part of the builder, of the obligations and responsibilities of engagements based upon the incomplete drawings or vaguely-worded specifications of an incompetent architect.

272. The profession of the architect and the trade of the builder are sometimes carried on by the same person: but this union of the directive and executive functions is not to be recommended; in the first place, because the duties of the workshop and the builder's yard leave little

time for the study of the higher branches of architectural knowledge; and, in the second place, because the absence of professional control will always be a strong temptation to a contractor to prefer his own interests to those of his employer, however competent he may be to design the buildings with the execution of which he may be charged.

During the present century, the impulse given to our arts and manufactures, and the improvements effected in the internal communications of the country, have given rise to the execution of many extensive works requiring for their construction a large amount of mechanical and scientific knowledge; in consequence of which a new and most important profession has sprung up during the last thirty years, occupying a middle position between those of architecture and mechanical engineering, viz., that of the civil engineer. The practice of the architect and of the civil engineer so closely approximate in many respects, that it is difficult strictly to draw the line of demarcation between them; but it may be said in general terms that, whilst the one is chiefly engaged in works of civil and decorative architecture, such as the erection of churches, public buildings, and dwelling-houses, the talent of the other is principally called forth in the art of construction on a large scale, as applied to retaining walls, bridges, tunnels, lighthouses, &c., and works connected with the improvements of the navigation and internal communications of the country.

273. The business of the surveyor is often carried on as a distinct branch of architectural practice; and, as the title of surveyor is often appropriated by those who have no real claim to it, a few words on a surveyor's duties may not be here out of place.

Surveyors may be divided into three classes; land surveyors, engineering surveyors, and building surveyors.

The business of an engineering surveyor, as distinguished from that of a land surveyor, chiefly consists in the preparation of accurate plans, sections, and other data

relative to the intended sites of large works, which may be required by the architect or engineer preparatory to making out his working drawings, and in conducting levelling operations for drainage works, canals, railways, &c.

The building surveyor prepares, from the drawings and specifications of the architect or the engineer, bills of quantities of intended works, for the use of the builder, on which to frame his estimates; and, in the case of contracts, these bills of quantities form the basis of the engagements entered into by the builder and his employer, the surveyor being pecuniarily answerable for any omissions. The surveyor is also employed in the measurement of works already executed or in progress; in the latter case, for the purpose of ascertaining the advances to be made at stated intervals, and is engaged generally in all business connected with builders' accounts.*

274. The following is the general routine of proceedings in the case of large works. It will readily be understood that in small works subdivision of labour is not carried to such an extent, the architect superintending the works himself, without the aid of a clerk of the works, and the builders taking out their own quantities.

I. The general design having been approved of, and the site fixed upon, an exact plan is made of the ground, the nature of the foundation examined, and all the levels taken that may be required for the preparation of the working drawings.

II. The architect makes out the working drawings, and draws up the specification of the work.

III. A meeting is held of builders proposing to tender for the execution of the proposed works, called either by public advertisement or private invitation, at which a surveyor is appointed in their behalf to take out the quantities. Sometimes two surveyors are appointed, one on the part of the builders, and one on the part of the

* See "Student's Guide for Measuring and Estimating Artificer's Work," 2nd edition, 8vo, 1853.

architect, who take out the quantities together, and check each other as they proceed.

IV. The surveyor having furnished each party proposing to tender, with a copy of the bills of quantities, the builders prepare their estimates, and meet a second time to give in their tenders, after which the successful competitor and the employer sign a contract, drawn up by a solicitor, binding the one to the proper execution of the works, and the other to the payment of the amount of their cost at such times and in such sums as may be set forth in the specification.

V. The work is then set out,* and carried on under the

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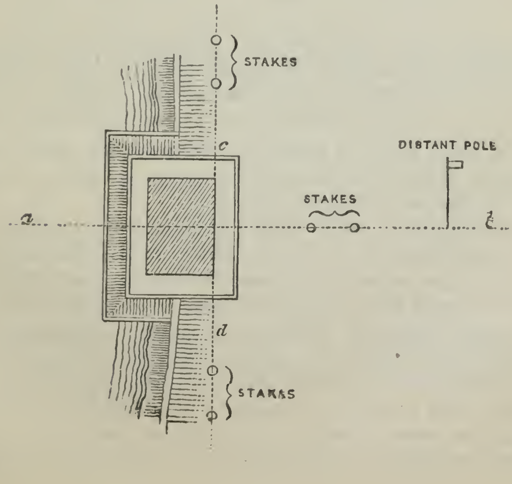
* *On Setting-out Work.*—The determination of the exact position of an intended building being sometimes difficult to accomplish, a few remarks on the subject may be acceptable.

The setting out of the leading lines is simple enough on level ground, where nothing occurs to interrupt the view, or to prevent the direct measurement of the required distances; but to perform this operation at the bottom of a foundation pit, blocked up with balks and shores, and ankle-deep in slush, requires a degree of practice and patience not always to be met with. Let us take a simple case, such as the putting in the abutment

Fig. 108.



constant direction of a foreman on the part of the builder, and on the part of the architect under the superintendence of an inspector or clerk of the works, whose duty is to be constantly on the spot to check the quality and quantity of material used, to see to the proper execution of the work, and to keep a record of every deviation from the drawings that may be rendered necessary by the wishes of the employer, or by local circumstances over which the architect has no control.

The work is measured up at regular intervals, and

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of a bridge or viaduct, any error in the position of which would render the work useless (see fig. 108). The leading lines having been laid down on the drawings, the first thing to be done, before breaking ground, is to set out the centre line very carefully with a theodolite and ranging rods for a considerable distance on each side of the work, and to fix its position by erecting poles, planed true and placed perfectly upright, in some part of the line where there is no chance of their being disturbed.

Next, the exact position of the abutment on the centre line would be decided upon, and fixed by setting out another line at right angles to the first, as *c d*, which would also be extended beyond the works, and its position fixed by driving in stakes, the exact position of the line on the head of the stake being marked by a saw-cut .

These guiding lines having now been permanently secured, the plan of the abutment may be set out on the ground, the dams driven, and the earth got out to the required depth. By the time the excavation is ready for commencing the work, it generally presents a forest of stays, struts, and shores, that would defy any attempt at setting out the work on its own level; it must, therefore, be set out at the level of the top of the dam, and the points transferred or *dropped* as follows:—

First, the position of the centre line is ascertained by reference to the poles, and, nails being driven into the timbers at the sides of the dam, a fine line is strained across; the position of the line *c d* is found, and a second line strained across in the same way. In a similar manner other lines are strained from side to side at the required distances, the lengths being measured from the line *c d*, and the widths from *a b*, until the outline of the foundation course is found; the angle points are then transferred to the bottom of the excavation by means of plumb-lines, and the work is commenced, its accuracy being easily tested by measurements from the lines *a b* and *c d*, until it is so far advanced as to render this unnecessary.

payments made on account to the builder, upon the architect's certificate of the amount of work done.

VI. The work being completed, the extras and omissions are set against each other, and the difference added to or deducted from the amount of the contract, and the whole business is concluded by the architect giving a final certificate for the payment of the balance due to the builder.

275. *Plan of Site.*—In preparing the plan of the site of any proposed works, the operations of the surveyor will generally have to be extended beyond the spot of ground on which the building is to stand. The frontages of the adjacent buildings, and the position of all existing or contemplated sewers, drains, and watercourses, should be correctly ascertained and laid down. Sketches drawn to scale of the architectural features of the adjacent buildings, if in town, and accurate outline sketches of the *incidents* of the locality of the intended operations, if in the country, should accompany the plan, that the architect may try the effect of his design before its actual execution renders it impossible to remedy its faults.

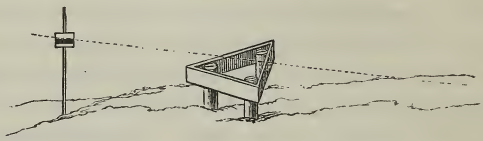
By the careful study of all these data the architect may hope to succeed in making his works harmonise with the objects that surround them; without them, failure on this head is almost a certainty.

276. *Levels.*—Where the irregularities of the ground are considerable, it is necessary to ascertain the variations of the surface before the depth of the foundations and the position of the floors can be decided upon.

It also frequently happens that the levels of the floors and other leading lines, in a new building, are regulated by the capabilities of sewerage or drainage, or by the heights of other buildings with which the new work will ultimately be connected, as in the case of new streets. It therefore becomes of importance to have simple and accurate means of ascertaining and recording the relative heights of different points. For this purpose both the spirit level and the mason's level are used

277. Where the ground to be levelled over is limited in extent, and the variations of level do not exceed 12 feet, the heights of any points may be found with the mason's level in the following manner. (*See* fig. 109.)

Fig. 109.



In a convenient place, near the highest part of the ground, drive three stout stakes at equal distances from each other, and nail to them three pieces of stout plank, placed as shown in the cut, their upper edges being adjusted to the same horizontal plane by means of the mason's level. The level being then placed on this frame, an assistant proceeds to the first point of which the height is required, holding up a rod with a sliding vane, which he raises or lowers in obedience to the directions of the surveyor, until it coincides with a pair of sights fixed at the bottom of the level; the height of the vane will then be the difference of level between the top of the levelling frame, and the place where the staff was held up.

278. The above and similar methods will suffice for taking levels in a rough way for the ordinary purposes of the builder; but where great accuracy is requisite, or where the levels have to be extended over a considerable distance, as is often the case in drainage works, the use of a more perfect contrivance is necessary, and the spirit level is the instrument principally used for this purpose.

The spirit level consists of a telescope mounted on a portable stand, and furnished with screw adjustments, by means of which it can be made to revolve in a horizontal plane, any deviation from which is indicated by the motion of an air-bubble in a glass tube fixed parallel to the telescope.

The eye-piece of the telescope is furnished with cross-wires, as they are technically termed, made of spiders' thread, of which the use will be presently explained.

279. The levelling staff, now in common use, is divided into feet, tenths, and hundredths, in a conspicuous manner, so that, with the help of the glass, every division can be distinctly seen at the distance of one hundred yards or more. The mode of conducting the operation of levelling is as follows:—

The surveyor having set up and adjusted his instrument, the staffholder proceeds to the point at which the levels are to commence, and holds up his staff perfectly upright and turned towards the surveyor, who notes the division of the staff which coincides with the horizontal wire in the telescope, and enters the same in his level-book; the staffholder then proceeds to the next point, and the reading of the staff is noted as before; and this is repeated until the distance or the difference of level makes it necessary for the surveyor to take up a fresh position. While this is being done, the staffholder remains stationary, until, the level being adjusted again, he carefully turns the face of the staff so as to be visible from the instrument in its new position, and a second reading of the staff is noted, after which he proceeds forward as before for a fresh set of observations.

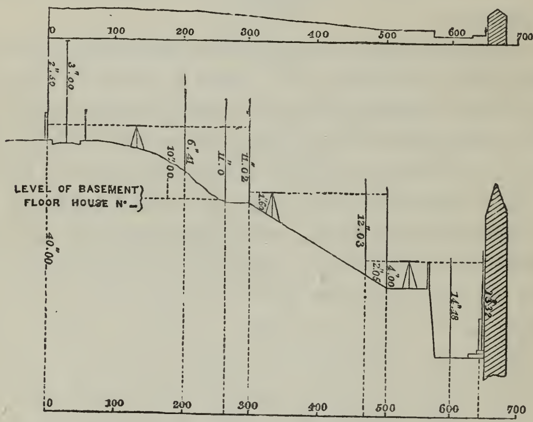
280. In every set of observations the first is called a Backsight and the last a Foresight. The remaining observations are called intermediates, and are entered accordingly. It will be seen that an error in an intermediate reading is confined to the point where it occurs; but a mistake in a back or foresight is carried throughout the whole work, and therefore every care should be taken to insure accuracy in observing these sights.

281. The surveyor should commence and close his work by setting the staff on some well-defined mark, which can readily be referred to at any subsequent period, such as a door-step, plinth of a column, &c. These marks are called

bench marks, written B M, and are essential for either checking the work or carrying it on at a subsequent period.

282. The reduction of the levels to a tabular form for use is a simple arithmetical operation, which will be readily understood by examination of the annexed example of a level-book, and of the accompanying section,* fig. 110

Fig. 110.



The difference between the successive readings in any set of observations is the difference of level between the points where the staff was successively held up, and by simple addition or subtraction, according as the ground rises or falls, we might obtain the total rise or fall of the ground above or below the starting point; but as this would require two columns, one for the total rise, and one for the total fall, it is simpler to assume the starting point to be some given height above an imaginary horizontal *datum line*,

* In plotting sections of ground, it is usual to make the vertical scale much greater than the horizontal, which enables small variations of level to be easily measured on the drawing without its being extended to an inconvenient length. This is shown in the lower half of fig. 110. The upper part of the figure shows the section plotted to the same horizontal and vertical scale.

drawn below the lowest point of the ground, to which level all the heights are referred in the column headed total height above datum line.

283. The accuracy of the arithmetical computations is proved by adding up the foresights and backsights, and, deducting the sum of the former from that of the latter (the height of the first B M having been previously entered at the top of the page as a backsight), the remainder will be the height of the last B M, and should agree with the last figures in the column of total heights.

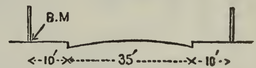
284. In levelling the site of a proposed building, if no suitable object presents itself for a permanent B M for future reference, a large stake, hooped with iron, should be driven into the ground in some convenient place where it will not be disturbed. The height of this stake being then carefully noted and marked upon the elevations and sections of the building, it will serve as a constant check on the depths of the excavations and the heights of the different parts of the work, until the walls reach the level of the principal floor, when it will no longer be required.

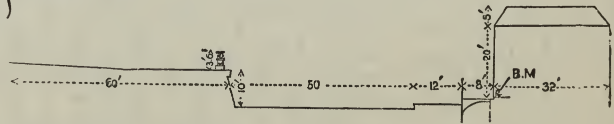
285. We must not leave the subject of levels without mentioning a very useful instrument, called the water-level, which consists of a long flexible pipe, filled with water, and terminating at each end in an open glass tube. When it is required to find the relative heights of any two points, as, for instance, the relative levels of the floors of two adjoining houses, the two ends of the tube are taken to the respective points, the tube being passed down the staircases, over the roofs, or along any other accessible route, no matter how circuitous, and the required levels are found by measuring up from the floors to the surface of the water, which will of course stand at the same level at each end of the tube

WORKING DRAWINGS.

286 The architect being furnished with the plan and levels of the site of his operations, and having caused a

Readings of the Staff.			Difference of readings.		Reduced levels.		Remarks.
Back sight.	Inter-mediate.	Fore sight.	Rise.	Fall.	Total height above datum line.	Distance in feet.	Levels of Building Ground at —— (Date).
40.00 Height of 1st B M above datum.							
2.50	...	...			40.00	—	B M on doorstep of garden, No. — Park Road.
	3.00	...	...	0.50	39.50	30	On centre of Park Road.
	10.00	...	...	7.00	32.50	...	Level of basement floor at No. — * * * Terrace.
	11.00	...	...	1.00	31.50	260	Terrace walk.
1.60		11.02	...	0.02	31.48	300	
2.05		12.03	...	10.43	21.05	475	
	4.00	...	...	1.95	19.10	500	
	14.18	...	...	10.18	8.92	600	Centre of Lower Road.
		13.02	0.86	...	9.78	...	B M top of doorstep, No. — Lower Road.
46.15		36.37					
36.37							
9.78	Reduced level of last B M.						





careful examination to be made of the probable nature of the foundation by digging pits or taking borings, proceeds to make out his working drawings.

It is not sufficient for the execution of working drawings that the draughtsman should be acquainted with the ordinary principles of geometrical projection. He must also be thoroughly conversant with perspective, and with the principles of chiascuro, or light and shade, or he will work at random, as the geometrical projections which are required for the use of the workmen give a very false idea of the effect the work will have in execution.

287. Working drawings may be divided under three heads, viz.:—Block plans, General drawings, and Detail drawings:—

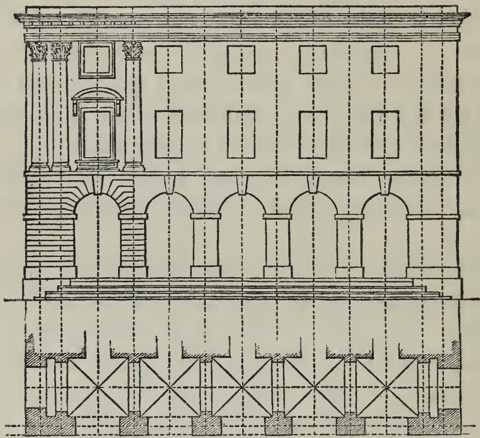
I. *Block Plans.*—These show the outline only of the intended building, and its position with regard to surrounding objects. They are drawn to a small scale, embracing the whole area of the site, and on them are marked the existing boundary walls, sewers, gas and water mains, and all the new walls, drains, and water-pipes, and their proposed connection with the existing ones, so that the builder may see at a glance the extent of his operations.

A well-digested block plan, with its accompanying levels, showing the heights of the principal points, the fall of the drains, &c., is one of the first requisites in a complete set of working drawings.

II. *General Drawings.*—These show the whole extent of the building, and the arrangement and connection of the different parts more or less in detail, according to its size and extent. These drawings consist of *Plans* of the foundations, and of the different stories of the building, and of the roofs; *Elevations* of the different fronts; and *Sections* showing the heights of the stories, and such constructive details as the scale will admit of. These drawings are carefully figured, the dimensions of each part being calculated, and its position fixed by reference to some well-defined line in the plans or elevations, the position of

which admits of easy verification in all stages of the work. This is best done by ruling faint lines on the drawings, through the principal divisions of the design, as shown in fig. 111, where the plan and elevation are divided into com-

Fig. 111.



partments by lines passing through the centres of the columns from which all the dimensions are dated each way These centre lines are, in the execution of the work, kept constantly marked on the walls as they are carried up, so that they are at all times available for reference.

By this means, the centre lines having been once carefully marked on the building, any slight error or variation from the drawings is confined to the spot where it occurs, instead of being carried forward, as is sometimes the case, to appear only when correction is as desirable as it is impossible.

The use of these centre lines also saves much of the labour of the draughtsman, as they form a skeleton, of which only so much need be filled up as may be required to show the design of the work.

III. *Detailed Drawings.*—These are on a large scale, showing those details of construction which could not be

explained in the general drawings, such as the framing of floors, partitions, and roofs, for the use of the carpenter; the patterns of cast-iron girders and story posts for the iron-founder; decorative details of columns, entablatures, and cornices, for the carver; the requisite details being made out separately, as far as possible, for each trade; which arrangement saves much time that would otherwise be wasted in referring from one drawing to another, and, which is still more important, insures greater accuracy, from the workman understanding better the nature of his work.

In making the detailed drawings, every particular should be enumerated that may be required for a perfect understanding of the nature and extent of the work. Thus, in preparing the drawings for the iron-founder, every separate pattern should be drawn out, and the number stated that will be required of each.

This principle should be attended to throughout the whole of the detailed drawings, as, in the absence of such data, it is very difficult to prepare correct estimates for the execution of the work without devoting more time to the study of the drawings than can generally be obtained for that purpose.

SPECIFICATION.

288. The drawings being completed, the architect next draws up the specification of the intended works. This is divided under two principal heads—1st, the conditions of the contract; and 2nd, the description of the work.

The title briefly states the nature and extent of the works to be performed, and enumerates the drawings which are to accompany and to form part of the written specification.

289. *Conditions of Contract.*—Besides the special clauses and provisions which are required by the particular circumstances of each case, the following clauses are inserted in all specifications:—

1. The works are to be executed to the full intent and

meaning of the drawings and specification, and to the satisfaction of the architect.

2. The contractor to take the entire charge of the works during their progress, and to be responsible for all losses and accidents until their completion.

3. The architect is to have power to reject all improper materials or defective workmanship, and to have full control over the execution of the works, and free access at all times to the workshops of the contractor where any work is being prepared.

4 Alterations in the design are not to vitiate the contract, but all extra or omitted works are to be measured and valued according to a schedule of prices previously agreed upon.

5. The amount of the contract to be paid by instalments as the works proceed, at the rate of — per cent. on the amount of work done, and the balance within ——— from the date of the architect's final certificate.

Lastly. The works are to be completed within a stated time, under penalties which are enumerated.

290. *The description of the works* details minutely the quality of the materials, and describes the manner in which every portion of the work is to be executed, the fulness of the description depending on the amount of detailed information conveyed by the working drawings, care being taken that the drawings and specification should, together, contain every particular that is necessary to be known in order to make a fair estimate of the value of the work.

291. The chief merit of a specification consists in the use of clear and explicit language, and in the systematic arrangement of its contents, so that the description of each portion of the work shall be found in its proper place; to facilitate reference, every clause should be numbered and have a marginal reference attached, and a copious index should accompany the whole.

BILLS OF QUANTITIES.

292 The surveyor being furnished by the architect with

the drawings and specification, proceeds to take out the quantities for the use of the parties who propose to tender for the execution of the work. This is done in the same way that work is measured when executed, except that the measurements are made on the drawings with a scale instead of on the real building with measuring rods.

293. In taking out quantities there are three distinct operations: 1st, taking the dimensions of the several parts of the work and entering them in the dimension book; 2ndly, working out the quantities from the dimensions, and posting them into the columns of the abstracts, which is called *abstracting;* 3rdly, casting up the columns of the abstracts and bringing the quantities into bill.

294. The dimension book is ruled and the dimensions entered as in the following examples:—

No.	Dimension.	Quantity.	Description.
	ft. in.	ft. in.	
16	14 0		
	0 10	38 10	Memel fir framed joists to front room ground floor.
	0 $2\frac{1}{2}$		

In this example, the work measured consists of sixteen joists, each 14 ft. long and 10 in. deep and $2\frac{1}{2}$ in. thick, and the total quantity of timber they contain amounts to 38 ft. 10 in. cube.

Dimension.	No. of bricks in thickness.	Quantity.	Description.
ft. in.		ft. in.	
20 6	$2\frac{1}{2}$	235 9	Stock brickwork in mortar to front wall, from footings to 1st set-off.
11 6			

This example needs no explanation.

295. In preparing the abstract for each trade, the surveyor looks over his dimensions to see what articles he will

have, and rules his paper into columns accordingly, writing the proper heads over each.

The principal point to be attended to in abstracting quantities is, to preserve a regular rotation in arranging the different descriptions of work, so that every article may at once be found on referring to its proper place in the abstract.

No fixed rules can be given on this head, as the form of abstract is different for every trade, and must be varied according to circumstances; but, as a general principle, articles of least value should be placed first. Solid measure should take precedence of superficial, and superficial of lineal, and miscellaneous articles should come last of all; or in technical terms, the rotations should be, 1st, cubes; 2nd, supers.; 3rd, runs; and, lastly, miscellaneous.

296. In bringing the quantities into bill, the same rotation is to be observed as in abstracting them, care being taken that every article is inserted in its proper place, so that it may readily be found in the bill.

The limits of this volume prevent our going into much detail on the subject of builders' accounts, and we must therefore confine ourselves to laying before the reader a skeleton estimate, which will give him a tolerable idea of the manner in which the several kinds of artificers' work are abstracted and brought into bill.

297. Estimate for the Erection of ——— at ——— for ———, according to Specification and Drawings numbered 1 to —, prepared by ——— Architect.

(Date.)

FOUNDATIONS.

yds.	ft.				£	s.	d.
—	—	cube	Excavation to foundations (including cofferdams, pumping, &c. . .	at —	—	—	—
—	—	,,	Concrete	,, —	—	—	—
ft.	in.						
—	—	,,	Timber in piles driven — ft. through (describe the material), including ringing, shoeing, and driving, but not ironwork	,, —	—	—	—
—	—	,,	Do. in 6-in. planking, spiked to pile-heads	,, —	—	—	—

Carried forward . . . £— — —

FOUNDATIONS *continued.*

cwt.	qrs.	lbs.			£	s.	d.
			Brought forward .				
—	—	—	Wrought iron in shoes to piles . .	at —	—	—	—
			Total of foundations to be carried to summary		—	—	—

BRICKLAYER.

yards	ft.				£	s.	d.
—	—	supl.	Reduced brickwork in mortar . .	„ —	—	—	—
—	—	„	Do. do. in cement . .	„ —	—	—	—
sqrs.	ft.						
—	—	„	Tiling (describing the kind, whether plain or pantiling, if single or double laths, &c., &c.)	„ —	—	—	—
yds.	ft.		Bricknogging to partitions . .	„ —	—	—	—
—	—	„	Paving (of various descriptions) .	„ —	—	—	—
—	—	„	And all other articles valued per yard superficial.				
ft.	in.						
—	—	„	Gauge arches	„ —	—	—	—
—	—	„	Facings (with superior description of bricks, specifying the quality) .	„ —	—	—	—
—	—	„	Cutting to arches or splays . .	„ —	—	—	—
			And all other work valued by the foot superficial.				
—	—	run	Barrel or other drains (specifying size, &c.)	„ —	—	—	—
—	—	„	Tile creasing	„ —	—	—	—
			And all other articles valued by running measure.				
		Nos.	Chimney pots, each; bedding and pointing sash and door frames, each; and all miscellaneous articles .		—	—	—
			Total of bricklayers' work to be carried to summary . . .		—	—	—

MASON.

yds.	ft.				£	s.	d.
—	—	cube	Rubble walling	„ —	—	—	—
—	—	„	Hammer-dressed walling in random courses	„ —	—	—	—
ft.	in.						
—	—	„	Stone (describing the kinds) . .	„ —	—	—	—
—	—	supl.	Labour on above (as plain work, sunk, moulded or circular work) . .	„ —	—	—	—
—	—	„	Hearths, pavings, landings, &c., beginning with the thinnest . . .	„ —	—	—	—
—	—	„	Marble slabs, beginning with the thinnest and inferior qualities .	„ —	—	—	—
—	—	run	Window sills, curbs, steps, copings, &c.				
—	—	„	Joggle joints, chases, &c. . .	„ —	—	—	—
			Carried forward . .		£—	—	—

MASON *continued.*

					£	s.	d.
			Brought forward . . .				
		Nos.	Mortices and rail holes, &c.—dowels, cramps, and other articles numbered		—	—	—
			Total of mason's work to be carried to summary	£	—	—	—

CARPENTER AND JOINER.

sqrs.	ft.				£	s.	d.
—	—	supl.	Labour and nails to roofs, floors, or quarter partitions . . .	at—	—	—	—
—	—	,,	Battenings and boardings according to description	,, —	—	—	—
--	—	,,	Floors, according to description, beginning with the inferior and ending with the best descriptions . .	,, —	—	—	—
			And so on for all work valued by the square.				
ft.	in.						
—	—	cube	Memel fir, according to description, as fir bond, fir framed, wrought and framed, wrought, framed, and rebated, &c.	,, —	—	—	—
—	—	,,	Do. proper door and window cases .	,, —	—	—	—
			Then oak and superior descriptions of timber, in the same way.				
			Then the superficial work, as—				
—	—	supl.	½-in. deal rough linings, and so on with the different thicknesses of deals according to the labour on them; arranging them according to their thickness and the amount of labour on them, beginning with the thinnest	,, —	—	—	—
			Then oak plank or mahogany in the same way.				
			Then take the framed work, as—				
—	—	,,	1¼-in. deal square-framed inclosure to closets, and so on with the rest of the framed work, as doors, shutters, sashes, frames, &c., according to description	,, —	—	—	—
			Then the work valued by running measure, as—				
—	—	run	2¼-in. Spanish mahogany moulded, grooved, and beaded handrail .	,, —	—	—	—
			Then the numbers, as—				
		Nos.	Mitred and turned caps, fixing iron balusters, &c.	,, —	—	—	—
			Lastly — The Ironmongery, every article of which should be carefully described	,, —	—	—	—
			Total of carpenter and joiner's work to be carried to summary .	£	—	—	-

Quantity	Description	Rate	£	s.	d.
	Slater.		£	s.	d.
sqrs. ft.					
— — supl.	Countess, or any other kind of slating, according to description . .	at —	—	—	—
ft. in.	Then slate slab, as—				
— — „	Inch shelves, rubbed one side, beginning with the slabs of least thickness, and arranging them according to the labour bestowed on them .	— „	—	—	—
	Then the work valued by running measure, as—				
— — run	Patent saddle-cut slate ridge . .	— „	—	—	—
	Lastly the numbers, as—				
Nos.	Holes, cut, &c.	— „	—	—	—
	Total of slater's work to be carried to summary	£	—	—	—
	Plasterer.				
	First the superficial quantity of plastering, as—		£	s.	d.
yds. ft.					
— — supl.	Render float and set to walls, beginning with the commonest, and proceeding through the different descriptions of two and three coat work up to the stuccos and superior work	— „	—	—	—
	Then the whitewashing, distempering, &c.	— „	—	—	—
	Next the run of cornices, architraves, reveals, &c., as—				
ft. in.					
— — run	Plain cornice to drawing-room, 14-in. girt	— „	—	—	—
	And lastly the numbers, as—				
Nos.	4 mitres, 1 centre flower, 30 in. diameter, &c., &c.		—	—	—
	Total of plasterer's work to be carried to summary . . .	£	—		—
	Smith and Iron-Founder.				
tons cwt. qrs. lbs	Begin with the cast-iron, as—		£	s.	d.
— — — —	Cast iron in No. 4 girders, including patterns, painting, and fixing .	— „	—		—
	N.B.—State the No. of patterns.				
	Then the smaller castings, as—				
	Railings, balconies, columns, &c. .	— „	—	-	—
	Then the wrought iron, as—				
— — — —	Wrought iron in chimney bars, straps, screw bolts, railings, &c. . .	— „	- -	—	- -
	Then the articles sold by running measure, as—				
yds. ft.					
— — run	Cast-iron gutters, water-pipes, &c. .	— „	—	—	—
	Carried forward . . .	£	—	—	—

	SMITH AND IRON-FOUNDER *continued.*			
	Brought forward . . .			£ s. d.
	Lastly the numbers, as—			
Nos.	Stoves, coal-plates, stable-fittings, &c. .			— — —
	Total smith and iron-founder's work to be carried to summary . .		£	— — —
	BELL-HANGER.			
	Number the bells, and describe the mode of hanging, as—			£ s. d.
Nos.	— bells hung with copper wires in concealed tin tubes, with bells, cranks, and wires complete . .	„	—	— — —
	And then enumerate the ornamental furniture to the different pulls .	„	—	— — —
	Total of bell-hanger's work to be carried to summary . . .		£	— — —
	PLUMBER.			
cwt. qrs. lbs.				
— — —	Cast lead laid in gutters, hips, ridges, flats, cisterns, &c.; including all solder, wall hooks, nails, &c. .	„	—	£ s. d. — — —
— — —	Milled do. do. . .	„	—	— — —
	Then socket, rain-water, and funnel pipes, and other work valued by			
ft. in.	the lineal foot, as—			
— — run	Inch drawn pipes	„	—	— — —
	Lastly the numbers, as—			
Nos.	Joints, plugs, and washers, air traps, brass grates, cocks, copper balls, pumps, water closets, apparatus, &c.			
	Total of plumber's work to be carried to summary . . .		£	— — —
	PAINTER.			
yds. ft.				
— — supl.	Of painting, according to description, specifying the number of oils, and whether common or extra colours, beginning with the work in fewest coats and finishing with the most expensive descriptions . . .	„	—	£ s d. — — —
ft. in.	Then the running work, as—			
— — run	Skirtings, plinths, window sills, &c.	„	—	— — —
	Lastly the numbers, as—			
Nos.	Frames, squares, chimney pieces, &c. .	„	—	— — —
	Total of painter's work to be carried to summary		£	— — —

				£	s.	d.
		GLAZIER.				
ft.	in.					
—	— supl.	Glazing, according to description, specifying size of squares and quality of glass	at —	—	—	—
		Then the stained and other ornamental glass; and, lastly, the plate glass.				
		Total of glazier's work to be carried to summary	£	—	—	—

				£	s.	d.
		PAPER-HANGER AND DECORATOR.				
yds.	ft.					
—	— supl.	Distempering, according to description	„ —	—	—	—
ft.	in.					
—	— „	Scagliola slabs do. . . .	„ —	—	—	—
yds	ft.					
—	— run	Gold mouldings	„ —	—	—	—
	Nos.	Pieces of paper hung, according to description, including preparing walls	„ —	—	—	—
		—Hanging, lining, paper, and pumicing do.	„ —	—	—	—
	„	Dozen of borders	„ —	—	—	—
		Total of paper-hanger and decorator's works to be carried to summary	£	—	—	—

		£	s.	d.
SUNDRIES.				
Temporary fencings—watching and lighting works		—	—	—
Office for clerk of works		—	—	—
District surveyor's fee		—	—	—
Fire insurance		—	—	—
Surveyor's charge for bills of quantities . .		—	—	—
Total sundries to be carried to summary . .	£	—	—	—

		£	s.	d.
SUMMARY OF BILLS.				
Foundations		—	—	—
Bricklayer		—	—	—
Mason		—	—	—
Carpenter and joiner		—	—	—
Slater		—	—	—
Plasterer		—	—	—
Smith and iron-founder		—	—	—
Bell-hanger		—	—	—
Plumber, painter, and glazier		—	—	—
Paper-hanger and decorator		—	—	—
Sundries		—	—	—
Total amount of estimate	£	—	—	—

298. The surveyor furnishes the builder, whose tender is accepted, with copies of the drawings from which the quantities have been taken off.

By reference to these, the builder can at all times satisfy himself that the detailed drawings, furnished for the execution of the work, contain nothing beyond what he has contracted for.

Copies of the drawings and specification are attached to the contract deed, and are signed by the builder and other parties respectively concerned.

299. It scarcely ever happens that a large undertaking can be carried into execution without considerable departure from the contract designs, especially in the matter of foundations and underground work; the exact nature and extent of which must often be uncertain until the works are commenced.

To provide for these contingencies without setting aside the contract, the builder's estimate is accompanied by a schedule of prices at which he undertakes to execute any additional work that may be required, or to value any work that may be omitted. This schedule should be very carefully drawn out, so that there shall be no dispute as to its meaning; thus, under the head of brickwork, it should be clearly understood whether centering is included in the price named, or whether it is to form an additional charge; with iron-founder's work, whether the price includes patterns, and so on with every description of work.

300. For taking out quantities, surveyors are allowed a commission of $2\frac{1}{2}$ per cent. on the cost of the work, and they are responsible to the builder for any omissions which may have to be made good by the latter.

301. Architects are remunerated by a commission of 5 per cent. on the amount expended under their direction, besides travelling expenses, salary of the clerk of the works, and occasionally other charges, according to circumstances.

APPENDIX OF NOTES AND ILLUSTRATIONS.

Note A, Page 13.—Retaining Walls.

The author, in the preface to the earlier editions, stated that authors prior to that date, from having neglected to take into consideration the friction of earth or gravel upon itself, had rendered the formulæ at which they had arrived, giving the conditions of stability of retaining walls, &c., of little or of no value in practice. He quotes Mr. Gwilt, who, in his "Encyclopædia of Architecture," Article 1,584, states that "he leaves out of question the rules of Dr. Hutton, as being absurd and incomprehensible;" but rightly adds that Hutton's formulæ, upon Hutton's data, are correct, and only require the correction for friction to make them agree with modern practice.

We need not, in a work so elementary as this, discuss that question here. The author, however, wrote at a period anterior to the publication of the formulæ and rules given by Professor Moseley, in his "Engineering and Architecture," and by Professor Rankine, in his volume of "Mechanics applied to Civil Engineering."

To both of these the student may be referred who desires thoroughly to understand the subject generally; the more advanced student will find a mass of important matter, theoretical and experimental, scattered through English and foreign engineering literature, and will derive great advantage by studying the examples with the conditions in which they were produced by some of the more celebrated engineers at home and abroad.

Note B, Page 30.—Easing Down Centering.

Since the date of the earlier editions of this work two methods of easing down centering—both, however, proposed at a considerably anterior period—have been brought into use with success and advantage. The first of these consists in substituting for the great chase wedges, and placed in the same position in which those are shown in Fig. 25, short but strong and powerful screw-jacks. By these the easing down is effected without the necessity for those tremendous

blows from a battering-ram necessary to start large chase wedges, and the danger of the wedges becoming so set together that they cannot be started at all, which has ere now happened, is avoided. The second method consists in supporting the centering at like points to the above by shallow iron, or strong timber, boxes filled with *dry* sand, which is permitted to run out by a lateral aperture, like sand from a common hour-glass, when the lowering is to occur. This has been found to answer well on the Continent, and also in India, in respect of some of the large viaduct arches upon the Great East Indian Railway.

Note C, Page 42.—Fire-proof Floors.

The student will do well to make clear his notions as to what are the conditions requisite in a floor, still more in an entire building, that it shall be rightly entitled *Fire-proof*. The vast mass of so-called floors and buildings are mere deceptive shams.

In the loose language of every day converse, as well as in much that in type ought to be more precise, anything is called a fire-proof floor or building, provided well-known combustible materials, such as timber, does not enter into the skeleton of the structure. The word is even rather audaciously applied to structures such as the so-called fire-proof flooring of Fox and Barrett's patent, in which a very considerable proportion of timber is employed, though shut up from the eye, and, we may add, from the free air, which, as Mr. Dobson remarks, is essential to its durability. Neither these floors nor those so extensively employed in the north of England and in Scotland for factory floors, as shown in section in Fig. 50, nor a multitude of other constructions, patented or otherwise, are really fire-proof at all. The most that can be said for them is that *they may delay* the spread of conflagration.

Upon the subject of fire-proof construction the student should consult various papers in the "Minutes of Proceedings of the Institution of Civil Engineers," and in the leading technical journals, and the works on the subject of the late Mr. Braidwood, of the London Fire Brigade, and of Mr. Young, recently published.

Note D, Page 47.—Roofs of Large Span.

A narrow limit is set to the clear span of roofs when they are constructed of timber, as will be readily seen by the student who has mastered properly the elements of physics as applied to structure.

The modulus of compression of all such timber as can be commanded in sufficient quantity in the necessary long and straight lengths, and at a cheap enough rate, is so low that the crushing up, both laterally and in the end way of the grain, fixes their limit. The use of iron has, however, given an immense extension to the powers of the engineers in producing roofs of vast clear span. Two hundred and fifty feet, which, unless at prodigious cost, approaches the practical limit of span in timber roofs with any permanent covering heavier than sheet

copper or zinc, is but the starting-point for future great roofs in iron, or still more in steel.

There can be no doubt that roofs of such material of 1,000 feet span may, with perfect ease and without any prohibitory cost, be safely produced.

And if full advantage be taken in the structural details of the tensional resistance of steel bars, probably double that span, if ever required, would not prove too heavy a tax upon the existing resources of the engineer. The iron roof of the St. Pancras Station, London, of the Midland Railway, now in progress, from the design of P. W. Barlow, Esq., C.E., is probably the largest in span yet attempted.

Note E, Page 59.—Zinc Coating, &c

The coating of wrought-iron and cast-iron with zinc, or with some alloys of zinc and lead, or zinc and tin, into which, when in fusion, the iron is dipped with certain preparations and precautions, has become extensively practised since M. Sorel, a Frenchman, first proposed the process, which has been the subject of many inferior British patents now expired. As a method of protection against the weather, *i.e.* against the conjoint effects of air and moisture, coating with *pure* zinc, if thoroughly well done, is tolerably effectual when applied to *wrought* iron. It is never so when applied to cast-iron. Nor is it, as a protection, of the slightest value upon either wrought or cast-iron, if these are exposed to the atmosphere of our coal-burning cities. The cast-iron plates of the roof of the Houses of Parliament present a lamentable proof of this fact, and wrought iron equally acted on may be seen in numberless places in London and other English towns.

In the pure atmosphere of the country—in agricultural districts and those not too near the sea, where the saline spray carried in by storms acts upon it—zincked or galvanised iron, as a covering, may be trusted, especially in dryer climates than ours, such as Canada or Australia.

Zinc itself, even the purest, such as that supplied by Mossilman, or the Vieulle Montagne Company, is not proof against the corrosive action of the smoke and sulphur-laden atmosphere of our coal-burning towns and manufacturing districts.

Upon the whole subject of the action of air and water upon the metals employed in the construction, the student will consult with advantage the four reports of Mr. Robert Mallet, prepared by the desire of the British Association for the Advancement of Science, and published in the volume of reports of that body.

Note F, Page 62.—Heating and Ventilation.

The student who desires to make himself well acquainted both with the theory and best practice as respects the heating and ventilation of buildings, should study the recently published work by General Morin —"Etudes sur la Ventilation," 2 vols., 8vo., Paris. In no single work

will be found so much and such sound and reliable information; but the subject is a very wide one, and no architectural student can be deemed instructed thoroughly in this important branch of his profession who has not consulted a very wide range of literature relating to it. A few of these treatises we may especially refer him to:—Tredgold on Heating and Ventilation, now getting a little antiquated; the Reports on the Heating and Ventilation of Pentonville and other Model Prisons; those on the same in relation to the Houses of Parliament, and those of the commission appointed to inquire into the means of heating and ventilating barracks and other apartments of relatively small size.

Note G, Page 68.—Preservation of Timber.

In addition to the several processes described in the text, the student should also be referred to the method of M. Boucherie, of at once seasoning and securing against decay timber in its green state, by causing the still living timber to take up by its capillary vessels a solution of sulphate of copper; and a still more recent French invention, consisting in preventing the external attack of those fungous sporules which initiate decay, by superficially *charring* to an extremely small depth the whole of the surfaces of finished timber, *i.e.* the wood cut to the size, &c.

This is effected by rapidly passing over it a powerful flame produced by a coal-gas and air blow-pipe, or by the flame driven forth by air-blast from a coke fire in a small hollow furnace. Accounts of both these processes may be found in the transactions and journals of a technical class during the last few years.

Note H, Page 75.—Steel Manufacture.

Since the date of the original edition of this volume, several new and important processes for the production of steel have been invented and brought into practical use. For a full account of these the student should refer to Percy's "Metallurgy of Iron," or other recent systematic works on metallurgy.

The only two to which we need here briefly refer are the production of steel by a slight modification of the puddling process, by which ordinary wrought iron is produced. The steel thus obtained is called "puddled steel," and that procured by Mr. Bessemer's process, or by blowing common air through cast iron in a state of fusion. The cast iron must either contain some manganese, or iron containing that in alloy must be added in fusion during the process of blowing through to produce good steel. By either of the above processes excellent steel of various qualities, some equal to the best cast steel of cementation, may be produced.

Both processes have already greatly reduced the price and increased the supply of steel, and the Bessemer process seems almost certain to revolutionise, before long, the whole iron trade, as well as all the

arts of construction, more or less, in proportion as they are dependent at present on wrought or cast iron.

Note I, Page 77.—Cast Iron, &c.

Although what the author has stated on the subject of the classes, properties, and manipulation of cast irons is well founded, his treatment of the subject, which is a large and complex one, is necessarily very incomplete. No student of the arts of construction, whether in the direction of engineering or of architecture, should deem himself educated until he has learnt enough of chemical metallurgy to read and make his own what has been written upon the physico-chemical history and proportions of iron in its three distinct states of cast iron, steel, and wrought iron—all highly complex bodies, and endowed with properties as remarkable as any in the range of entire nature. No single work will be found to give a clearer view of these properties and relations than Karsten's "Metallurgie di Fer," translated from the German, original by Kuhlmann (3 vols. 8vo). The student who once has mastered the scientific *principles* upon which the properties and changes in them of iron in its various states depend, will find himself in possession of a treasure that in practice will be as "a lantern to his feet" during his whole career in life, and, wanting which, all the random facts he may pick up out of popular text-books, journals, &c., will prove to him but a deceptive and disconnected jumble.

Note K, Page 80.—Tensile Resistance.

The table here given of the ultimate tensile resistances of these several materials must be accepted as only approximate and with caution.

No cast iron, but white mottled cast iron of great rigidity, will stand a tensile strain of 7¾ tons per square inch; nearly all the cast iron employed in architectural and engineering structures is torn asunder at a strain of four or five tons, and should never be trusted in tension at a strain of more than two tons per square inch for a dead pull, or one half of that for a sudden or impulsive strain.

Cast iron in different sized specimens of various qualities differs in tensile strength enormously—as much as 7 to 1.

It is not the popularly supposed *brittleness* of cast iron that makes it unsafe in tension, for within its range of resistance it is *less brittle* (*i.e.* more extensible or ductile) than wrought iron, but the small total range of its tensile resistance; whereas in wrought iron, this range being far larger, it constitutes for such moderate stress as that material should ever be exposed to in practice an actual margin of safety.

What the author meant by stating that *wrought iron* is torn asunder by ten tons and *English bar iron* by twenty-five tons, to the square inch of section, it is difficult to conjecture. Some British bar or plate irons of extreme softness and ductility, and therefore of extreme value for

certain special purposes, are torn asunder by a strain of only about seven tons per square inch, while rigid and very little extensible bar iron occurs constantly which is not torn asunder under thirty tons per square inch. Steel, again, in bars, whether made by cementation, by puddling, or by the Bessemer process, can be produced with a tensile resistance of eighty tons or upwards per square inch, and the same material drawn into wire assumes a resistance of 120 tons per square inch.

The student must guardedly distinguish in every case, and above all in calculating dimensions to be given in practice to parts, whether to be exposed to tension, compression, or transverse strain, between *ultimate resistance* and *safe resistance;* what difference must be given under given conditions to the dimensions of the parts, or, what is the same thing, *what co-efficient*, as that of assumed ultimate resistance, he must employ, so as to ensure a sufficient margin or factor of safety, should be sought for by a careful study of a few of the most important of the mass of works treating of such subjects. Of these we may notice for his information the parliamentary "Report of the Commission on Railway Structures in Iron," Hodgkinson's edition of "Tredgold on Iron," Fairbairn's "Reports of Experiments to British Association," Edwin Clarke's "Britannia and Conway Bridges," and the able digests of the whole subject in his "Mechanics applied to Civil Engineering."

Mr. Kirkaldy's volume is valuable as an important contribution of facts, but the student should be warned to accept his generalisations with caution. Several of these are not in accordance with known facts of molecular physics, nor even with a correct interpretation of his own experiments, which are themselves creditable to his industry and zeal.

For the metallurgic properties of iron and steel exposed to strains, and especially as respects impulsive strains, Mr. Mallet's work on the "Materials employed in the Construction of Artillery" may be consulted.

Note L, Page 88.—Strains on Girders.

The margin of safety given in the text of two-thirds is, by consent of a large number of well-informed engineers, deemed too small—three-quarters factor of safety for *statical loads*, *i.e. dead weight*, is better and safer practice. Where the load is a rolling load, or variable, or liable by any chance to become a *dynamic load*, *i.e.* a *suddenly applied* or *impulsive load*, then double the above margin of safety should always be allowed, though it is not uncommon in English practice to allow for dynamic strain a section of resistance that shall reduce the strain upon the unit of section to only one-sixth that of the breaking strain.

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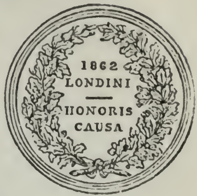

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